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Editorial:

Freedom of Scientific Publication . . . .

Before the war, the results of scientific research were published as promptly as it was technically possible. Scientific journals vied in providing facilities for rapid publication of the latest discoveries. Open and rapid publication permitted "cross-fertilization" of research in different laboratories, minimized the otherwise inevitable duplication of effort and fostered a feeling of community of research workers all over the world. Restriction of publication was practiced in industrial research, but this did not affect the progress of science, particularly since large concerns learned to rely on continuous leadership in research and development rather than on "secret processes."

In the Soviet Union, too, the freedom of scientific publication was on the whole, unimpeded; because of the absence of industrial competition, technological research was published even more freely than in America. Only occasionally, did the Soviet Government decide that a certain field of research was of particular importance for national security and placed it under secrecy restrictions.

What was once a minor exception became a general rule all over the world during the war. Nuclear physics, bacteriology, electronics, became closed preserves which only scientists with appropriate badges were permitted to enter.

THE DECLASSIFICATION PROBLEM

A year has passed since the Truman-Attlee-King declaration proclaimed the intention to return to the free publication of the results of fundamental research. Only the release of information on technological procedures was to await the establishment of guarantees against misuse of atomic energy for destructive purposes.

In pursuance of this policy, the Manhattan District appointed a Declassification Committee (declassification being the technical term for the removal of the designation "secret" from official documents). The report of this committee was approved by General Groves and an organization was set up to handle the declassification procedure. (This organization was described in Colonel Hutchinson's article in the November 1 issue of the Bulletin.) A list of publications thus far released is reprinted elsewhere in this issue.

Professor Weisskopf points out, in a letter also published in this issue, that the scientists in Europe are growing pessimistic about ever receiving any information on the real progress of science in America during the war. The facts given above show that these apprehensions are somewhat extreme, and that certain steps towards the restoration of a free flow of scientific information are being made. However, in order to be able to say that the Tolman Committee declassification plan has actually been implemented, not only must the present dribble of largely accidental and often unimportant releases be replaced by a flow of paper covering the most important scientific progress made during the war, but information on declassification papers must be disseminated and the papers themselves made available to all who need them.

The McMahon Bill has instructed the Atomic Energy Commission to be guided by the principle that the "dissemination of scientific information relatng to atomic energy should be encouraged to provide free interchange of ideas which is essential to scientific progress." This dissemination is needed not only to restore the international co-operation in science and to "appease" the foreign scientists, but to permit American science to resume its progress on a broad front, and to prevent confusion and duplication of effort bred by war-time compartmentalization and discrimantion between scientists with and without badges.

WHERE TO DRAW THE LINE?

Beyond the immediate task of publication of what has already been declared publishable, the criteria by which the science is being divided into "open" and "secret" fields need fundamental re-examination. In the Truman-Attlee-King declaration, the distinction was made between "fundamental research" and "technological know-how." Similar language was retained in the McMahon Bill. The British Atomic Energy Bill, reported in this issue, substitutes another definition. It defines as restricted, information "pertaining to an existing or proposed atomic energy plant, and important for national security." In practice, the American declassification rules also involve what General Groves has referred to as a "jig-saw cut" through the body of scientific information, leaving on the "secret" side things "important for national security." The article of Colonel Hutchinson implied that this fine surgical operation is being performed with complete success.

Now it has been said that the boundary between fundamental research and technological know-how is artificial and indistinct; but certainly it is much more real that the line between scientific information "important" and "unimportant" for national security. There is no use deceiving the public and Cngress that we are having our cake and eating it—adhering to the policy of freedom of science but not giving away anything which

(Continued on last page)

IN THIS ISSUE

Science, Government and Industry in Britain — E. V. Appleton
Foundations of Freedon in Science — M. Polanyi
British Atomic Energy Act
Scientists' Role in International Relations — H. A. Kramers
UN Atomic Energy Commission
Present Status of Declassification
List of Manhattan Project Declassified Documents
Technological Control of Atomic Energy Activities — A Report by American Scientists
Atomic Energy and U.S. Patent Policy — C. W. Ooms
Letters to the Editor

Science, Government and Industry in Britain

. . . . . *Sir Edward V. Appleton*

I have chosen as the subject "Science, Government and Industry" because I believe that the proper direction of scientific effort and the proper application of the results of such effort is one of the most important challenges of our time. Stimulated by the realization of the magnificent services rendered by scientists in support of the Allied forces during the war, science and its consequences have become a matter of interest to the ordinary citizen. It is no new thing to the thoughtful mind that science has practical and social consequences. What is new is that the general public is now sharply aware of them. As a prominent newspaper man recently expressed it to me "Science is news, as never before."

Now I think it can be said that this awakening to the importance of scientific work on the part of the public has been due in large measure to the fact that, during war, events move fast, and the four stages of research, development, production and use follow so rapidly on the heels of one another that the practical consequence of scientific effort is clear for all to see. The public has naturally concluded that if science can solve so many of the problems of war-time, it should play a similar role in solving the problems of peace. The problems that confront us now are, in an ultimate analysis, the provision of work, homes, food, health and safety—safety from aggression—for all; and these problems depend for their solution on the maintenance, in some degree, of the same kind of partnership between Government, Science and Industry which grew up during the war.

Now one of the most striking results of our war-time experience has been the brilliant success of our University research workers in solving war problems entirely remote from their peace-time interests. Various reasons have been advanced for their success. It has been pointed out that they had fresh minds. It has also been stated that, in approaching a difficult task, "They didn't know it couldn't be done." It has further been claimed that they had a better background of fundamental principles than the majority of those with whom they worked. I do not profess to be able to assign the result to any one of these causes. But what cannot be doubted is that University conditions certainly do, somehow, generally insure the maintenance of mental adventurousness and lively imagination so necessary for scientific progress; and we, in Britain, believe that in planning the future of our Scientific Civil Service we must try to ensure that conditions are encouraged that will bring these same things about.

Another deduction I make from our war-time experience is that the most successful applications of science have resulted from the closest possible collaboration between the scientist and the military staff. The great naval writer Rear-Admiral A. T. Mahan once drew attention to the long period which used to elapse between changes of weapons and the consequent changes of tactics. He attributed this lag to "the inertia of a conservative class." Fortunately we can be satisfied that in the war that has just ended such gaps have not been unduly long. This has been due not only to the close collaboration between scientist and service man but also to the fact that in many cases scientists have assisted their service colleagues in working out plans for the use of new weapons. Indeed it has been realized that the field in which the scientist can usefully operate extends far beyond that of the laboratory.

My third comment on our war-time experience relates to subject matter. We have seen a mighty effort resulting in outstanding developments in weapons and instruments, culminating in the atomic bomb. By no means all this effort has been wasted, even if judged solely by its peace-time scientific interest and importance. But in this intensive drive many inviting scientific avenues have had to be just noticed and passed by. When fundamental work has had to be done, as in the case of nuclear physics or in radio wave propagation, it has necessarily had to be objective in character and relevant to the major target. What I may call free fundamental work—free in the sense that its selection is dictated solely by man's curiosity—has been almost wholly in abeyance. We cannot recognize the return of peace in any better way than by changing all that. Our priorities must be revised. We have in many fields been living on our scientific capital which now stands urgently in need of replenishment. For this purpose the British Government has set its own priorities, for the time being, as regards the release of scientific staff from Government service in the following order:

(1) Universities and fundamental research.
(2) Civil Science, Government and Industrial.
(3) Defense Science.

You will see in this a complete reversal of the priorities which obtained in wartime.

CIVIL SCIENCE

In turning now to the future we note that, as in most countries, scientific research in Britain is, in the main, carried out by three types of organizations which differ somewhat in motives and objectives. These three organizations are:

(a) **Universities** and like institutions carrying out what I shall call free fundamental research. This is carried out for the purpose of extending the endless frontiers of knowledge if I may use the graphic expression of Dr. Vannevar Bush. This type of research, the result of intellectual curiosity and the love of truth for its own sake, is carried out without regard to any immediate or future useful application.

(b) **Government establishments** carrying out what I may call objective fundamental research and also applied research. By objective fundamental research I mean research designed to give insight and understanding rather than any special immediate practical result. It is called objective because it is relevant to some field of practical importance and

(c) **Industrial Research Laboratories** carrying out mainly applied research but also, in enlightened firms, a certain amount of objective fundamental research.

But I do want to emphasize here that there is no sharp differentiation between my divisions into (a) free fundamental (b) objective fundamental, and (c) applied, research. However, I do find them a more convenient classification than the older division into "pure" and "applied" research which always had, to my mind, the suggestion of snobbishness about it. A certain mathematician once stated that "Bessel functions are beautiful functions in spite of their many applications," and I well remember hearing a British scientist boast that he could claim that what he had done could never be the slightest use to anybody. It turned out to be an idle boast, as we might have expected. His work has become of the greatest practical importance.

(1) UNIVERSITY SCIENCE

It is a remarkable fact that University scientific research is of relatively modern growth. Scientific research, as we know it today, began in the seventeenth century when the experimental method replaced the method of ex-cathedra statement or argument by which, since the Middle Ages, man had endeavored to find truth. The scientific method of inquiring by observation, theory and experiment has often been attributed to Francis Bacon though my own view is that of Dr. William Gilbert, the physician of Queen Elizabeth

The above is an address delivered on Nov. 19th as the inaugural lecture under the Arthur Dehon Little Memorial Lectureship at Massachusetts Institute of Technology.

and Fellow of my own College, St. John's at Cambridge, has a stronger claim to be counted its author. But the teaching of the experimental method did not form part of the University curriculum in the seventeenth and eighteenth centuries, and laboratories did not form part of University equipment. Early in the nineteenth century, however, teaching laboratories for science were instituted and research became a spare time activity of professors and lecturers. From small beginnings this has developed till it is now an accepted part of University tradition that teachers of scientific knowledge should also advance that knowledge. It is moreover important to note that though carried out in a spirit of pure inquiry this free fundamental research has shown a surprising capacity for being useful.

Then we also look to our Universities not only to make science but to train makers of science. We look to them for the supply of trained scientific workers who will later occupy positions in University, Government and Industrial Laboratories. We find that this training in research is best accomplished by a senior research worker acting as supervisor to a group of research students which should not be large.

We must never forget the outstanding importance of the exceptional man in this respect. Most of the really great advances in science have been accomplished by small teams of workers of this kind led by a man with ideas. As one concerned, to some extent, with the organization and support of science in Britain, I believe that a vital task is to see that these leaders, these men with ideas and inspiration, lack neither disciples, assistants or equipment. When such needs have been satisfied they should be left alone.

(2) GOVERNMENT SCIENCE

I now turn to Government Research of which, even apart from Defense Research, Government in Great Britain conducts a great deal that perhaps you would regard as being primarily the responsibility of Industry or other bodies. Here we definitely enter the utilitarian field.

Though their object was in the main the satisfaction of their disinterested intellectual curiosity, the natural philosophers of the seventeenth century easily recognized that the results of their experiments could lead to important applications. Not only did they appreciate the importance of what Bacon called *experimenta lucifera* — experiments of light, which illuminate our knowledge of the nature of things, but they also appreciated what he called **experimenta fructifera,** experiments of fruit, which yielded knowledge which could be applied, as Bacon pointed out, to extend the empire of man and to ameliorate the condition of man which he regarded as wretched. In his "New Atlantis" Bacon described what he calls Salomons House, a kind of national research laboratory which had the object of arriving at "the knowledge of causes, the secret motions of things, and the enlarging of the bounds of human empire, to the effecting of all things possible." You will be interested to note that of the staff for this national laboratory he writes "We have three that try new experiments such as themselves think good. These we call Pioneers. We have three that bend themselves, looking into the experiments of their fellows and cast about how to draw out of them things of use and practice for man's life and knowledge. These we call Benefactors. Lastly we have three that raise the former discoveries by experiments into greater observations, axioms and aphorisms. These we call Interpreters."

Somewhat later, the scholarly Boyle, too, discoursed largely on the "Usefulness of the Experimental Natural Philosophy" pointing out the usefulness of mechanical disciplines to natural philosophy and how the goods of mankind may be increased by the naturalist's insight into Trades, and of doing by physical knowledge what is wont to require manual skill.

The close of the eighteenth century brought from America to Great Britain and Europe that singularly gifted Secretary, General and Statesman, Benjamin Thomson Count Rumford who, while making several purely scientific discoveries of the highest importance, found practically the whole of the inspiration of his scientific work in his desire to use science to improve the living conditions of the common people. He was, I think, the first, conscientiously and deliberately, to utilize science as a means of increasing the health, happiness and comfort of his fellow man.

Very little was heard in the nineteenth century of the possibly useful applications of science which was still studied in the main for its pure intellectual interest. I recently, however, came across a most interesting article written in the Fortnightly Review in 1873 in which the author, Dr. George Gore, F.R.S., points out that scientific research is the only source of the new knowledge which is indispensable to national progress. As he says "Without new knowledge the thoughts of men run in circles and intellectual and material progress ceases."

After calling attention to the, what he calls, deplorable lack of support given to fundamental scientific research, he proposed that there should be formed state laboratories for original research.

Very little notice seems to have been paid to these advocates of State assistance in the prosecution of research for the national benefit in Great Britain until, in 1900, the National Physical Laboratory was founded with Government assistance.

It was set up largely as a result of the efforts of the late Lord Rayleigh who, in Britain, realized earlier than most how the progress of modern industry depended to an ever increasing extent on accurate measurements and precise knowledge of the properties of materials.

It required the impact of the first World War, however, seriously to awaken the British Government to the necessity for State action in regard to scientific research and, as a result, in 1915 the Department of Scientific and Industrial Research was established as a separate Department of State, under the Lord President of the Council who is advised by an Advisory Council. The Department of Scientific and Industrial Research is not, of course, concerned with the whole field of science. Agricultural Research and Medical Research are dealt with by sister organizations, also under the Lord President. There are, naturally, scientific experts in the Ministries responsible for defense, trade, food, health, fuel, transport and so on, so that, very wisely I think, there has been no attempt to confine scientific knowledge to one Ministry alone since it has to be applied by many.

The major part of Government civil research in the sphere of physical, chemical and industrial interest is, however, centered in a group of ten research organizations under the Department of Scientific and Industrial Research (D.S.I.R.) through which we try to provide a central scientific service for the executive departments of government and also to carry out research on matters of common interest to industry and to the community as a whole. That is the first function of the Department. Our second is the encouragement of research by industry itself, and more directly by fostering the formation of co-operative research associations, of which I shall have more to say later. Thirdly we assist, by means of grants, free fundamental research of timeliness and promise in Universities in Great Britain, and we endeavor to provide an adequate supply of trained research workers by means of maintenance allowances.

But before I mention further details of the Department's activities I would like to draw your attention, too, to the special position allotted by our founders to the Advisory Council which advises the Lord President on all the Department's research activities and expenditure. At present this expenditure is running at the rate of three million pounds per year. The Advisory Council is composed of men who have an expert knowledge of science or of industry and who serve in their purely personal capacity and not as representatives of any particular organizations to

which they belong. It was, when first formed, one of the first bodies composed of men outside Government to advise on policy for implementation inside Government. Individual members of the Advisory Council retire after five years' service.

In addition to the Advisory Council we have a Research Board or Committee to advise on the work on each of our research organizations. Each Board or Committee is, again, composed of independent members who are chosen by the Lord President for their special knowledge and experience. Thus, by way of our various advisory bodies, our university and industrial scientists and our industrial leaders exercise a direct influence on the activities of the Department.

I now turn to say a word or two about our own ten Research establishments. The full list of the Department's stations is as follows: National Physical Laboratory, Building Research Station, Chemical Research Laboratory, Food Investigation Organization (dealing with the storage and preservation of food), Forest Products Research Laboratory, Fuel Research Station, Geological Survey, Pest Infestation of Stored Products, Road Research Laboratory and Water Pollution Research Laboratory. Earlier in my talk to you this evening I referred to Count Rumford, who was born at Woburn, Massachusetts, as probably the first to apply the methods of science to problems connected with the primary domestic needs of mankind. It is singular coincidence, but many of the problems he investigated are precisely those for which we have thought it desirable to set up special laboratories. For example, his work on the economy of fuel, on the design of kitchen stoves and on the reduction of smoke from chimneys is paralleled by that of our Building Research Station on fuel economy, domestic heating appliances, and atmosphere pollution. His work on ventilation and the comfort conditions in rooms is similarly paralleled by that of our Building Research Station on the same subject. Similarly his work on the tractive force required to draw carriages having wheels of various widths over roads of different types has connections with that of our Road Research Laboratory. Rumford also carried out research on food, paying attention to its nutritional value, its economy and its efficient preparation; we also have a Food Research Organization. Finally, though there may be other comparisons which have escaped me, he invented his celebrated photometer and carried out researches on the lighting of rooms and the design of lighting fittings, activities which are continued today at the National Physical Laboratory.

I do not propose to weary you with a description of the work of all our stations. I shall select only one station as an example for brief comment, namely the Fuel Research Station.

A most important section of work of the present time is that of the National Coal Survey, which is conducted at nine laboratories of the various coal fields, with its headquarters at the Fuel Research Station. The purpose of the Survey is to determine the physical and chemical properties of our coals both as they occur in seams in the ground and as prepared for the market. On the basis of the data collected it is possible to indicate the most suitable uses of the different coals and to predict with considerable accuracy the probable properties of coal in seams that are as yet unworked.

The Coal Survey, in conjunction with the Geological Survey collaborates with the Coal Commission and the Ministry of Fuel and Power in assessing our national reserves of coal, which since 1942 have belonged to the nation. It will be seen that the data collected by the survey are essential in the planning of future mining operations if we are to use our not unlimited resources to the best advantage.

Now in considering the applications of science we must note the changing function of Government. In Graham Wallas's famous phrase it "has come to be engaged not merely in preventing wrong things from being done, but in bringing it about that the right things shall be done". In discharging this most positive function we find that, to an increasing extent, science is being used as part basis for the formulation of Government policy. A very interesting problem of organization therefore arises. We desire scientific knowledge to permeate the executive departments. How far, then, can a central scientific department serve these executive Departments, and in what way should its service be supplemented by scientific staff and scientific work within the executive Departments themselves? I do not pretend to be able to give, in answer to these questions, a simple formula which would be applicable to all cases. But quite extreme views have been expressed in Britain on this subject. It has been argued by some that all science should be made in a central scientific Department and none in the executive Departments. It has been correspondingly argued by others that each executive Department should have sufficient scientific staff to make all the science which it needs in the discharge of its own responsibilities. The latter answer seems to me to overlook the need for economy of scientific effort. Because the police need wireless, as do so many other civilian and military services, there seems no case for the Home Office to set up its own radio research unit if it can be equally well served by a central radio research organization. Correspondingly, there is no need for the Ministry of Health, which is responsible for our pure water supply, and the Ministry of Fuel and Power, which is responsible for our mining development, both having their own Geological Survey units. So I would argue that there are weighty economic reasons for the use of some, even if not all, common scientific services.

But, granted that there are some central scientific services, how can we insure that their work can be effective in the executive departments?

One solution of this difficulty is the appointment of a Scientific Advisor in each executive Department, who can

(a) identify the problems within his Department which are suitable for scientific treatment;

(b) see that these problems are passed to the appropriate research bodies able to solve them; and

(c) interpret the incoming scientific material for the special purpose of his Department. But I should stress that for such a scientific advisor to be effective it is necessary that he should be sufficiently senior in the Department hierarchy. His advice should be tendered to the highest level—the level at which policy is decided.

I have so far stressed the value of the work of D.S.I.R. to Government and, through Government, to the community. But there is also another link with the community, and that is through industry. In this connection the Department serves industry chiefly by conducting research on generic fundamental problems on the basis of which industry itself can make applications. The greater part of this research is what I called objective fundamental research. In this case the main quest is understanding. Here the scientist seeks physical or chemical insight, and even atomic insight, into certain fields of practical importance. This may relate to the corrosion of metals, the oxidation of fats, the toughness of meat, the warping of wood, the electronic changes in the ionosphere and so on. Armed with understanding, many practical problems are relatively easily solved. Very often a basic attack of this kind is the most fruitful and shortest route to the solution of a problem of practical importance. Also, very often quite unexpected and unsought applications are thrown up as by-products of such fundamental research.

(3) INDUSTRIAL RESEARCH

I now turn to the subject of industrial research which is conducted in Britain by private firms and by the industrial research associations. The larger firms, to an increasing extent, have their own laboratories, some of which are comparable in size and scope to the larger Government research laboratories. But these labor-

atories exist mainly in the newer industries which were, in any case, born and bred on science and to whom scientific research is the life blood. In many cases such firms carry out not only applied research, but also objective fundamental research relevant to their own interests. They are, of course, at liberty to keep the results of their scientific work to themselves, but in general they follow an enlightened policy and their staffs are important contributors to the world's scientific literature.

With a view to stimulating research by private firms the British Government has recently introduced certain fiscal changes. For many years now it has been possible fo a "trader" to count current revenue expenditure on scientific research undertaken in relation to his trade as a deduction in computing profits for income tax purposes. But as from 6th April of this year provision has been made whereby capital, as distinct from current, expenditure, is allowable for income tax purposes by five equal annual installments. For this purpose capital expenditure may relate, say, to the building of research laboratories or the installation of pilot-plants.

But in considering industrial research in Great Britain, we are at once faced with the fact that over 98 per cent of our firms employ less than a hundred workers, so that although it is admitted that research always pays a dividend if you do enough of it, to a small firm without considerable financial reserves industrial research on its own account must often appear as a risky adventure and beyond its means. This difficulty has been met to a considerable extent by the D.S.I.R. which, as I mentioned earlier, is charged with the duty of encouraging research in industry.

The main method by which we have done this is by the formation of Research Associations each on a co-operative basis to serve the needs of particular industries. These Research Associations are self-governing bodies formed on a national basis, financed mainly by the contributions of their member firms but supported by substantial grants from the D.S.I.R., the size of which is related to the amounts raised by the industries.

There are now thirty-five or more of these Research Associations and their expenditure on research is nearing one and a half million pounds per year, having risen from a little over a quarter of a million in 1934 to a half a million just before the war. I should not be at all surprised myself to see this figure more than doubled in the next few years. In the past six months it has heardly been possible to keep pace with the new research associations, so quickly are they being formed.

For a very modest contribution, less than the cost of a single junior research worker, a small firm is enabled by joining a Research Association to share in research costing thousands of pounds, and in some cases hundreds of thousands a year. The Research Associations also keep their members informed on scientific and technical developments throughout the world, provide them with advice on their day-to-day problems, and insure that the industry as a whole has an opportunity of receiving early knowledge of developments likely to affect the future of their industry.

One thing which I am afraid tended to hinder the growth of co-operative research in the past was the rather touching belief of many firms that they possessed knowledge and trade secrets which were unknown to their competitors, and that this might be revealed if they collaborated in research. The manner in which firms had to work together in the war has done much to destroy this fear. An interesting side-light on this matter are the remarks of the managing director of one of our leading aircraft firms. He said "When the war began, we thought that we knew a great deal more than our competitors, but when we were forced to share our knowledge with them, we found they knew about just as much as we did and that the gaps in their knowledge and ours were about the same. What surprised us all still more was that when we had to share our knowledge with our American allies, we again found that the gaps in their knowledge and ours were just about the same."

CONCLUSION

Perhaps I may be permitted to devote the last section of my discourse to personal views rather than to factual matters. I strongly believe that the scientific life should be one of intellectual adventure. It seems to me that this can characterize it whatever its objective. We must recognize and encourage the enthusiasm of the chase as well as the attainment of the objective. I also want to break down the old false barrier between the so-called pure and applied divisions of science, for the whole field seems to me essentially one and its parts are inter-dependent. We are sometimes sufficiently aware of possible practical applications not too far-distant for such recognition to influence our choice of subject. But we must beware of too much restriction of the scientific front. That is the way of arrogance and folly. Man is not all-prescient; and nature has many surprises.

As to the scientist himself, I believe that he should serve, and not dictate to, mankind. But he has the important dual mission, not only of uncovering nature, but also of interpreting it to his fellow men. Then, the consequences of scientific effort being understood by the community, any vital decisions on use must be taken together. Science is too serious a matter to be left to the scientists.

But here I am bound to confess that I see a certain danger, at any rate in my own country. I cannot but feel that there is a tendency in our educational system for scientific specialization to be introduced too soon. A scientific man should also be the complete "citizen of the world". He should not only be fit to live, but also fit to live with. This can only be brought about if his later specialized training is based, and continues to be based, on a broad cultural background. Only in this way can the scientist enjoy the necessary human fellowship with the rest of mankind. But with science destined to play such a vital part in moulding the future of our civilization, it seems to me essential that, in a democratic community, the public, who ultimately should control the destiny of the nation, should make its own effort towards understanding. Too often, and most regrettably, the average citizen is apt to associate science with magic and with something that gets into the headlines.

As a first step in this direction I feel that we should start with our educational system which, I think all would agree, should not be merely an implement of vocational training. It is not necessary to be a maker of science in order to understand its history, its content and its significance. There is a recently published American book which has made a great impression on many minds in my country. It is entitled "A State University Surveys the Humanities" and consists of a series of essays by members of the staff of the North Carolina State University. Among the many thoughtful and thought-provoking contributions to this scholarly volume there is one entitled "The Biological Sciences: The Sciences in the Humanities" by Dr. Robert E. Coker, who is strongly of the opinion that the general cultural value of science is not sufficiently appreciated in universities. He deplores the cultural distinction which is drawn between the arts and the sciences and believes "it arose and has persisted in part from the overconfidence of some scientists who have proclaimed a self-sufficiency for science. It derives also from the narrowly restricted vision of those who would teach the sciences as if they were useful only to equip individuals for earning a livelihood or to enable mankind to have more gadgets and physical comforts." In another passage in the same essay Dr. Coker enunciates his main thesis simply and boldly. "The sciences", he claims, "take high rank among the humanities." I believe he is right if the sciences are taught as they could be and should be.

The Foundations of Freedom in Science . . . .

. . . . . M. Polanyi

Whenever the basic institutions of science are at issue, scientists will find it necessary to reconsider with care the need for freedom in science and may wish to state the case for freedom and defend it before a wider public. There will thus arise a new interest in the deeper nature and justification of freedom in science.

Issues far outside scientific life will help to foster this interest today. The value that men attach to freedom has plunged our generation into a deep dive from which it is only climbing precariously out again. Scientists may want to help the world on its way back to freedom by making known how freedom operates in science.

THE NATURE OF FREEDOM IN SCIENCE

Freedom in science assigns to each mature professional scientist the task of conducting research with the aim of making the greatest possible contribution to science. Such a responsibility is a heavy one; but it is a free responsibility. The mature scientist chooses his subject at his own discretion and pursues it day by day in the same discretionary manner. He draws his own conclusions and stakes such claims as he thinks right. At no point of his research work is he subject to any specific instructions from any superior authority.

Freedom of scientific research is in harmony with some intensely personal impulses. The choice of a problem, its pursuit and final conquest are manifestations of the individual scientist's passion for discovery. They bring into play intellectual powers which are otherwise hidden and assert creative forces of a unique kind. An individualist philosophy would regard these personal impulses as the justification for freedom in science. But I find such a view rather superficial. For, clearly, not every strong personal impulse can claim respect and it remains therefore to be shown why those of the scientist should be respected.

A more fundamental approach is gained by examining what may be called the co-ordinative functions of freedom in science. A statement submitted recently by Dr. Enrico Fermi to the Senate Hearings on Science Legislation defines this function as follows:

> "Experience has indicated that the somewhat haphazard exploration of the field of knowledge that results from an intensive freedom of the individual scientific worker to choose his own subject is the only way to insure that no important line of attack is neglected."

We have here a plea for freedom in science on the ground of social efficiency. The discretionary powers which a system of freedom grants to scientists are said to constitute the only effective machinery for co-ordinating the efforts of individual scientists to the joint purpose of the advancement of science.

Now, usually one thinks of co-ordination as a process imposing restraint on the discretionary powers of individuals. Much of my argument will be concerned therefore with finding out how co-ordination is achieved in science by the opposite method of releasing the individual impulses in question.

THE COORDINATIVE FUNCTION OF FREEDOM

A first step towards the answer is easy to find by throwing a glance at a group activity in which co-ordination is totally absent. Take a number of people shelling peas. There is no occasion here, and no possibility, to adjust the work of one person to the work of another, for the value of their total achievement is simply proportionate to the sum of the peas shelled by each. Science cannot be conducted by such isolated efforts. Suppose scientists were kept a few hundred years strictly without any mutual communication. The total discoveries achieved by them would be little more than what is normally gained by science in a few years. No continued systematic growth of science would take place at all.

The co-ordinative principle of science is thus seen to consist in the adjustment of each scientist's activities to the results achieved by the others. Since such mutual adjustment depends on the independent decisions of each, its operations require the complete freedom of all.

It would seem that we are faced here with a basic principle leading quite generally to co-ordination without intervention of any co-ordinating authority. It is a simple principle of logic which can be demonstrated on quite trivial examples. Consider the piecing together of a jig-saw puzzle, and suppose we take a very large puzzle which would take one person a number of days to piece together. Assume further that we had a dozen players who would like to help. It would obviously be of little use to give to each a separate set of the puzzle to work on it in isolation, but it would greatly speed up the solution if all participants were allowed to work on the same set, each taking note of the results of the others and using them as their starting point.

The logic of this form of co-ordination can be reduced to even simpler terms. For every mathematical calculation carried out by successive stages of approximation may be taken to illustrate it. Each step in such a computation deals with one phase of a problem at a time and relies on the results of the earlier steps. This becomes particularly clear if we think of problems in which each step is operated at a different point in space. A common example of such a polycentric problem is the distortion of a rigid framework of joists pinned together at a large number of points. Given the elastic properties and the distribution of loads over all the pinpoints, the solution can be found by the "relaxation method" which consists in calculating the displacement of each pinpoint in turn in respect to its neighbors, the position of these being assumed for the moment as fixed. In passing from one centre to the next the displacement previously calculated for the others is always taken into account. If a large number of such calculations had to be quickly made for a given rigid framework, we could employ a team of calculators, and place each in charge of one particular pinpoint. They could all go on working independently merely notifying each other of their results and mutually taking these into account.

We have reduced here to the simplest terms the co-ordinative function of freedom. It seems to be based on the fact that in certain cases a joint task can be achieved by a group of participants who know not what the result of their joint efforts is to be and are not directed by anyone who knows it. The co-ordinative function of freedom in science would appear thus as merely an instance of the general logic of such spontaneous self-co-ordination; and scientific enquiry would be merely the pursuit of a peculiar kind of polycentric problem in which the participants happen to bring into play intensely personal impulses and an exceptional degree of creative judgment.

Such a statement however, would be seriously incomplete as it would fail to take into account the characteristic vagueness of the task pursued by science. The pieces of a jig-saw puzzle are bought in shops with the certainty that they will yield a solution known to the manufacturer. Processes of successive mathematical approximation advance towards a definitely foreseen end. Science does not proceed towards such pre-defined ends. In the meaning in which there exists a task of piecing together a jig-saw puzzle, or of solving a polycentric mathematical problem, the task of science cannot be said to exist at all. If we want

A speech delivered at the Bicentennial Celebration of Princeton University.

to understand spontaneous self co-ordination in science we must yet discover in what sense there does exist a common task of science.

Our first reaction may be to look for a definition in terms of explicit premisses underlying the scientific interpretation of nature. But there exists no strict set of suppositions on which scientists are agreed and have been agreed throughout the past centuries. Whatever premisses may be held in common among scientists they are not to be found formulated in definite precepts. They can therefore be said to exist only as implied in the practice of scientific enquiry. To the examination of this practice let us therefore turn.

THE COHERENT TRADITION OF SCIENCE

It is clear that the coherence of science is implied in every affirmation of discovery by a scientist. A claim to discovery expresses the scientist's conviction of having gained an element of truth which other scientists are bound to recognize; and his claim is also usually based on his recognition of discoveries made by other scientists. Moreover every new discovery claims to form an addition to the system of science as transmitted from the past. There is inherent therefore in each new claim to discovery the practical affirmation of a coherent system of truth which is capable of indefinite extension into yet unexplored regions.

For the extension of this system scientists rely on methods embodied in the common practice of research. Scientists accept, utilize and transmit certain traditional procedures and standards. They uphold certain traditional ideals.

This dedication of scientists to the advancement of an intellectual process beyond their control and to the upholding of values transmitted to them by tradition represents the sense in which science does possess and pursue a coherent task. Alternatively, we may express the existence of such a task by saying that scientists form a community believing in a certain spiritual reality and covenanted to the service of this reality.

Those who—whether within science or outside science—subscribe to these beliefs and underwrite this covenant affirm by implication the presence of a spontaneous co-ordination of independent creative impulses in science. They uphold freedom in science. Those who deny such metaphysical beliefs and repudiate such transcendent obligations deny by logical implication also the possibility of both self-coordination and freedom in science. They may not act by this logic but the implication remains true.

SCIENTIFIC OPINION AS GUARDIAN AND GUIDE

The organized forms of scientific life, publications, university posts, research grants and scientific distinctions form a system of opportunities and restraints for the pursuit of science. This system is governed by scientific opinion. Scientific opinion prevents cranks, frauds and habitual blunderers from gaining ground in science. At the same time it apportions credit to valid contributions, appraising and supporting their authors according to their merits. Those disciplinary and administrative actions are indispensable to science as cultivated today by thousands of contributors. By performing them, scientific opinion enforces the coherence of science, which is the basis of its freedom.

We can clearly see now the inadequacy of the individualist theory of freedom in science. Individual impulses are respected in science only insofar as they are dedicated to the tradition of science and disciplined by its standards.

Modern science depends for its material existence on support from outside. Scientific opinion which watches over coherence and freedom from within science cannot fulfill this function unless its decisions are respected outside science. In allocating their support to different scientific purposes, outside authorities must accept the guidance of scientific opinion. They would otherwise inevitably disrupt the coherence of science and undermine its freedom.

CONFLICT WITH EXTRA-SCIENTIFIC AUTHORITIES

Such are the foundations of freedom in science. It is easy to see why they may be called in question in the world today. The autonomy of science cannot be recognized by any government which denies transcendent reality to science. Inevitably, such a government will come in conflict with the autonomy of science.

Similar dangers may arise more incidentally wherever the responsibility for the expansion of scientific institutions falls to public authorities who are not sufficiently familiar with the nature of science. As guardians of the public interest they may feel reluctant to leave to scientific opinion full control over public funds allocated to science. Dazzled perhaps by the achievements of applied science in wartime—which had, quite rightly, been placed under the direct control of the political authorities—they may fail to recognize clearly the different nature of the quieter pursuits of pure research and not realize that these can be maintained only in complete independence.

THE CONCEPT OF FREEDOM IN SOCIETY

In my introduction to this paper I have said that by defending the foundations of freedom in science we may help people to recover a clear conception of freedom in general. The theory of scientific freedom which I have just outlined might indeed be found capable of extension to other fields of social life. There are other realities of the mind besides science and there exist transcendent obligations other than those which are particular to scientists. There exist great traditions which embody these realities and these obligations and which comprise all the main roots of our civilization. We have our tradition of intellectual honesty, which came to us from the Greeks; that of brotherhood, which we derived from Christianity; that of legal reason, which was the heritage of Rome; and that of tolerance which we were taught by Milton and Locke.

All these traditions form, like that of science, the premisses for an indefinite sequence of individual creative actions. Actions which are, or at least tend to be, spontaneously coherent, and the unrestrained interplay of which forms the constitution and essence of a free society.

The foundations of coherence and freedom in general may therefore be regarded as secure to the extent to which men uphold their belief in truth, justice, charity and tolerance and do in fact accept dedication to the service of these ideals. While on the other hand society may be expected to disintegrate and fall into servitude when men deny, explain away or even simply disregard these realities and transcendent obligations.

Disintegration may follow on the one hand the path of an individualist theory of freedom resulting in romantic self-love and civic indifference. Concurrently we may find that the institution of government is interpreted in terms of force, and that history is represented as the process of one clan liquidating another and one nation eliminating another.

Within such an outlook the ideal aspirations of man are rendered homeless. Fearing to confess themselves for what they are they seek embodiment in some social or racial theory of isolence. Thus we see arise that sceptical hard boiled form of fanaticism which is so characteristic of our age.

Man's rapidly increasing destructive powers will soon put the ideas of our time to a crucial test. Unless we radically re-affirm today the philosophic foundations of our civilization, the logical outcome of their present inadequacy will not be delayed for long.

The British Atomic Energy Act . . . .

As reported in Bulletin last month, the British Atomic Energy Bill was passed by the House of Commons on October 11 and is now awaiting passage in the House of Lords. The following summary of the Bill shows the similarities and the differences between the American and the British legislation.

PROVISIONS OF THE BILL

The "Atomic Energy Act 1946," the British counterpart of the McMahon Bill in the USA, contains 21 clauses. The following official memorandum summarizes their provisions:

The objects of the Bill are to empower the Minister of Supply to promote the development of atomic energy and to confer on him powers of control over the unauthorized production or use of atomic energy and over the publication of certain information.

The Minister is charged by **Clause 1** with the general duty of promoting and controlling the development of atomic energy (which is defined in Clause 18) and by **Clause 2** is given power to produce and use atomic energy, to carry out research, and to produce, handle and deal in any necessary articles. (The right to dispose of the energy produced was added in the House).

The Minister is empowered under **Clause 4** to obtain information concerning any materials, plant or processes connected with the production of atomic energy, and by **Clause 5** to enter and inspect any premises where he has reasonable grounds for believing that work on atomic energy is being conducted or that materials or plant relating to atomic energy are situated.

The Minister may search for minerals from which uranium and other prescribed substances (as defined in Clause 18) can be obtained **(Clause 6)** and may, by order, vest in himself the right to work such minerals and any ancillary rights necessary for such working **(Clause 7)**. Any order under Clause 7 will provide for compensation.

Clauses 8 and 9 enable the Minister to acquire compulsorily, but with provision for compensation, any materials, plant or contractual rights connected with atomic energy.

By **Clause 10** the Minister is given powers of control, by order, over the working of any minerals from which the prescribed substances can be obtained, and over the possession and movement of any of the prescribed substances or of any plant connected with atomic energy; but the Minister is to ensure, so far as practicable, the availability of materials and plant for research and educational purposes and for commercial purposes not related to atomic energy.

Clause 11 restricts the disclosure, without the consent of the Minister, of information concerning any existing or proposed plant for producing or using atomic energy. (This clause is given in full below).

Special provisions regarding inventions in relation to atomic energy are contained in **Clause 12.** The Comptroller General of Patents, Designs and Trade Marks is required to prohibit or restrict the publication of information concerning an application for a patent of this nature, and to notify the Minister, serving a copy of the notice on the applicant. The Minister may inspect the deposited documents; and, if he is satisfied that the invention is not of importance for purposes of defense, the ban on publication will be lifted by the Comptroller General. In addition, the clause prohibits, except with the written permission of the Comptroller General, the making of applications outside the United Kingdom, by a person resident therein, for the grant of patents in respect to such inventions, unless application for a patent for the same invention has already been made in the United Kingdom, and either no ban on publication has been imposed or any such ban has been lifted.

The powers of the Minister are extended by Clause 12 so as to include power to make, use, exercise or vend an invention for purposes relating to atomic energy; and the Minister may authorize the use of any drawing, model, plan or other document or information.

Clauses 13-21 contain "General Provisions." Among them **Clause 14** provides as punishment for individual offenses under the act, on conviction or indictment, penal servitude for not more than five years or a fine not exceeding 500 pounds, or both. Corporate bodies can be fined any amount the court thinks just, and their directors, general managers, secretaries and other officers are individually responsible for such offenses. **Clause 15** provides for Parliamentary review of all orders issued by the Minister under the act, with the right of either House to annul any one of them within 40 days after it has been laid before the Parliament.

Clause 18 gives the following definitions:

"atomic energy" means the energy released in any process, including the fission process, which involves the transformation of or reactions between atomic nuclei and has been influenced by special arrangements of matter or by other applied means, but does not include energy released in any process of natural transmutation or radio-active decay which is not accelerated or influenced by external means;

"minerals" includes all substances obtained or obtainable from the soil by underground or surface working;

"plant" includes any machinery, equipment or appliance, whether affixed to land or not;

"prescribed substance" means uranium, thorium, plutonium, neptunium or any of their respective compounds or any such other substance as the Minister may by order prescribe, being a substance which in his opinion is or may be used for the production or use of atomic energy or research into matters connected therewith.

FINANCIAL EFFECTS OF THE BILL

It is not possible in the present state of development of work on atomic energy to give an estimate of the total expenditure which may be incurred under the Bill.

The principal expenditure will arise from the exercise of the powers of the Minister under Clause 2. Expenditure of the order of 30 million pounds can at present be foreseen, but no figure can be given for the moment which may ultimately be involved.

Under Clause 3, the Minister may make grants or loans to encourage work on atomic energy; the Minister will be liable to pay compensation, under Clause 6, for damage caused by any work done for the purpose of discovering minerals and, under Clauses 7, 8, and 9, for any compulsory acquisitions effected thereunder but no estimate can yet be made of the amounts likely to be involved.

THE SECURITY CLAUSE; THE STAND OF THE BRITISH ATOMIC SCIENTISTS

A memorandum expressing certain criticisms of the Bill was prepared by Profs. Peierls and Massey and circulated among the members of the Association on July 8.

Of the four points of criticism made in the memorandum, the two most vital seemed to be the lack of statutory provision for technical advice to the Minister

and the far-reaching secrecy provisions of Clause 11, the latter being closely bound up with the wide definitions contained in Clause 18.

The Association's officers explained these views to members of the House of Commons, to the general public by way of a letter published by the "Times" on 8th October, and to the Ministry of Supply in person on 10th October.

The views of the Association of Scientific Workers were very similar, and a number of members of the House strongly urged the Government to agree to amendments in the senses proposed by the Associations. These efforts to amend the Bill were almost entirely unsuccessful, while new Government amendments have made the Bill still more restrictive—particularly by the deletion of the subsection Clause 11 that would have exempted from secrecy restrictions any plant designed solely for scientific research and educational purposes.

Clause 11 now provides:

(1) Subject to the provisions of this section, any person who without the consent of the Minister communicates to any other person any document, drawing, photograph, plan, model or other information whatsoever which to his knowledge describes, represents or illustrates

(a) any existing or proposed plant used or proposed to be used for the purpose of producing or using atomic energy;

(b) the purpose or method of operation of any such existing or proposed plant; or

(c) any process operated or proposed to be operated in any such existing or proposed plant;

shall be guilty of an offense under this Act.

Provided: that it shall not be such an offense to communicate information with respect to any plant of a type in use for purposes other than the production or use of atomic energy, unless the information discloses that plant of that type is used or proposed to be used for the production or use of atomic energy.

(2) The Minister shall not withhold consent under the last foregoing subsection, if he is satisfied that the information proposed to be communicated is not of importance for purposes of defense. (This provision was added by the Minister in Committee to replace the deleted provision—referred to by the Atomic Scientists Association—which provided for an exemption of plant designed only for scientific research and education).

(3) The Minister may by order grant exemption from this section in such classes of cases, and to such extent and subject to such conditions, as may be specified in the order.

(4) Where any information has been made available to the general public otherwise than in contravention of this section, any subsequent communication of that information shall not constitute an offense under this Act.

The Minister has promised "to free the ordinary laboratory tools of the research physicist which have no defense significance by excluding them from the terms of any order that he may make under Clause 10; and, as soon as the Bill becomes law, to confer with the physicists and scientists who will be affected, with a view to making an Order under Clause 11 to exclude those tools from the categories of plant about which communication is forbidden."

THE SPEECH OF PRIME MINISTER ATTLEE

The Bill was introduced by the Prime Minister, **Mr. Attlee.** Following are excerpts from his and other speeches in the House of Commons on October 8:

"I am quite sure hon. Members in all parts of the House will recognize the unique military, economic and international importance of this subject, and that those very unique conditions require very exceptional legislation.

"The full economic significance of atomic energy is not yet known. I do not think anyone has any doubt that there is here a possibility of revolutionary changes. Therefore, I think hon. Members of all parties will agree that development in this country is a prime responsibility of the Government. Today, we are not concerned primarily with the question of international control. That is a matter which is being worked out in the Commission set up by the United Nations organization. I do not think there is sufficient awareness, perhaps, of the dangers in this country. I am quite sure that that awareness is not quite so acute as it is on the other side of the Atlantic. But we have been watching with anxious care the deliberations of the Commission; and this Bill before the House, in one of its aspects, is an earnest sign of the Government's determination that the United Kingdom shall be ready to play its part, its full part, in any international scheme.

"This Bill has no background of political bearing. It is forced upon us by the very nature of this new invention. We are not introducing a sudden Bill for nationalization. We are taking the steps which any Government must take in dealing with an invention of such immense potential destruction. In fact, the task of development could not really be undertaken except by Government. There is, first of all, the very large expenditure in money and materials. There is uncertainty as to the results; and there is, of course, a thing we must watch all the time—the danger of disastrous accident if there were uncontrolled experiment.

"As the House knows, the Government have already set up a large research establishment, and we are arranging for the production of fissile material for that establishment, and for other purposes; and the responsibility has been placed with the Minister of Supply; and this Bill will give him the necessary powers to discharge that responsibility. The programme of work already approved will cost something like 30 million pounds, but the programme is being kept constantly under review, and it may well be that expenditure on a far greater scale may be necessary if we are to play our proper part."

The Prime Minister then reviewed the single clauses. Coming to Clause 11, he said:

"I draw special attention to Clause 11, which places restrictions on the disclosure of information. The production of atomic energy involves very complicated processes, it is really a major industrial effort, and until we can get international control, what is sometimes called the industrial 'know-how' must be kept under control. When I was in America the declaration made by the President of the United States, the Prime Minister of Canada and myself laid down this policy: until we can get the introduction of effective and forcible safeguards, there must be power to prevent the dissemination of information as to what is called the 'know-how'.

"We are presented with a rather difficult drafting problem as to where exactly to draw the line, where to get the security we need without impeding scientific research, and the conclusion we reached was that we should define in the Bill the information which should not be communicated concerning the energy plants, what they do and how they work, the provision for excluding information about plant in use for purposes other than atomic en-

ergy, provided that the connection with atomic energy is not disclosed. Our desire has been to make the thing watertight by giving the Minister full powers, including power to authorize a relaxation in particular cases. Also we desire to take away the onus which, as the Bill is drafted, rested on persons, requiring them to give information without knowing quite whether the information was right. As the Clause will be amended in Committee, that onus will be on the Minister. We also provide that where information has once been made available to the general public, if it is not in contravention of the Bill, it is freed from further control. We expect that in course of time there will gradually emerge classes of information which may be published. As a matter of fact today the great bulk of the technical information is necessarily in Government hands. It has been the result of work in Government establishments or under Government control, and there is there, therefore, the additional safeguard of the Official Secrets Act. If hon. Members will examine this Clause, I think they will find that it hits the mean between not giving away information that will endanger our security and, at the same time, not being unduly restrictive of scientific research."

Mr. Blackburn (Birmingham, King's Norton): Would the Prime Minister deal with the point that, instead of accepting the distinction which he pointed out earlier between fundamental research on the one hand and industrial 'know-how' on the other, the Clause is now so drafted as to cover the whole field, both fundamental research and industrial 'know-how' as well?

The Prime Minister: I do not think so.

THE OPPOSITION SUPPORTS THE BILL

On behalf of the opposition, the Bill was supported by Mr. Richard Law. He said, in part:

"This Atomic Energy Bill resembles with extraordinary fidelity the general run of Socialist legislation. In this Bill, as in all other Bills, the Government establish a monopoly. In this Bill, as in those other Bills, the Government endow a supposedly all-wise Minister with absolute and final authority. Here, as in other Bills, vistas are opened up of forms to be filled in, declarations to be made, inspectors to be placated, and so on, and compensation, not very clearly defined, is to be paid for those whose rights or property is wrested from them by the State. It is very much on the old model. Nevertheless, we on this side of the House propose to give our support to this Bill, even though it does resemble so very closely some other horses which have come out of the same stable and have not been conspicuously successful at recent race meetings.

"I think there are two main reasons why the House should give a Second Reading to this Bill. No layman can say with absolute finality and dogmatism that there will never be any physical, mechanical answer to the atomic bomb. It is conceivable, I suppose, that the same ingenuity which produced the bomb may, in time, produce its antidote. What we can say, and must say now, is that it seems unlikely in the physical field that there will ever be, as far as we can see, a complete antidote to this weapon. We are therefore left to look for a solution for defense—because we must have a defense—not in the physical field but in the political field. The only final defense I can see in the political field is some valid international agreement for the establishment of an international authority for the control of this new weapon. That is really the only ultimate defense. It is clear that it is going to be impossible to establish international control unless first we have established national control. This Bill is therefore the essential prerequisite of the final solution, if ever in fact we do reach a final solution. That is one reason why I suggest that the House, irrespective of party, must support the Bill this afternoon.

"The second reason is this. We are at present in a kind of interim position. We have not yet achieved a valid international agreement, no international authority has been set up, and with the limited information at my disposal I cannot see that there is any immediate prospect of such an authority being set up. From every point of view, from the point of view of the economic, medical or scientific development of this invention, as much as from the point of view of defense, we must ensure as far as we humanly can that we in this country, our scientists and our industry, are abreast of anything that is being done in any other country. That for the moment is the only solution which is left open to us during this interim period pending the establishment of an international authority.

Protests Small Science Representation in UNESCO

Prof. W. A. Noyes, President-Elect of the American Chemical Society, recently directed the following letter of protest to Ass't. Sec'y. of State William F. Benton:

Dear Mr. Benton:

I have received the list of members of the United States National Commission on Educational, Scientific, and Cultural Cooperation as well as the list of officers, including the executive committee, who were elected by the Commission at its first meetings.

Among the members of the Commission there seem to be only seven who could be said to represent science at all. Of these seven, three are university presidents, two are engineers, one a biologist, and the seventh, also a biologist, has retired from active life. Therefore of the seven, one engineer and one biologist may be said to be actively engaged in scientific work today. This is the total out of a list of 90.

Of the officers elected by the Commission, one vice president is a physicist, now a university chancellor no longer engaged in scientific work, and none of the others are scientists.

Among the list of societies asked to appoint delegates, only one is a large scientific society which might be said to represent any considerable group. Even this one is supported mainly by biologists and geologists and cannot be said to represent to any great degree chemists, physicists, and engineers.

The situation created by the very small representation of scientists both on the Commission and among the officers is a most unfortunate one. Scientists as a group tend to believe strongly in international cooperation, and indeed, scientific cooperation throughout the ages has been one of the few unifying influences. As matters stand today, however, it is doubtful whether you can count on the support of scientists for UNESCO. The executive committee is largely dominated by business men and professional educators. Those of us who have been ardent supporters of UNESCO are now confronted with a serious problem and our course of action in obtaining international cooperation is by no means clear. However, it is evident that we would be wasting our time in supporting an organization where the viewpoint of science is not fairly represented.

W. Albert Noyes, Jr.

Letters to the Editor . . . .

Personnel of the Atomic Energy Commission

. . . . . *Otto Beyer*

The Commission to be appointed under the provisions of the Atomic Energy Act of 1946 will have the responsibility of bringing into being a new and basic industry—the production of atomic energy. It will also have the task of guiding the utilization of this energy into socially useful channels.

How profoundly the production and use of atomic energy can affect the future of the Nation is evidenced in the language and scope of the Act. In this legislation Congress empowered the Federal Government to control the production, ownership and use of fissionable materials and provided the broad outlines of a program of administration designed to effectuate the Act's purposes.

Important phases of this administrative program were written into law in order to prevent the leakage of vital information, to assure the loyalty of employees, and to grant the Atomic Energy Commission discretion in the employment of key personnel without regard to the limitations of the Classification Act.

But neither the expressed purposes of the Act nor the legal safeguards which it provides are in themselves sufficient to ensure that the production of atomic energy for peaceful uses will be achieved in the most effective and expeditious manner. That result depends upon the selection of administrative and operating personnel who not only are loyal to the Federal Government but who also are motivated and inspired by a consciousness of the immensity and potentialities of the task ahead.

This applies, it goes without saying, to the Commissioners and the General Manager, whose selection and appointment is the responsibility of the President and the Senate. It is equally the case as to the Division heads called for in the basic law and the many administrators, supervisors, and employees who must be hired by the Commission.

The object of this article is to focus attention upon the importance of establishing personnel policies and practices designed to evoke from the men and women who will be engaged in this great experiment the wholehearted devotion so necessary to success.

Some of these policies and practices need no particular elaboration. Clearly enough, responsibility for personnel administration must be centered in a branch or department established for the specific purpose. Such a department would be charged, in collaboration with the appropriate agencies of the government, with recruiting and selecting personnel. It would, in this connection, develop job classifications and descriptions and establish the required system of personnel records. It would have the primary responsibility for developing techniques of indoctrination and training for new employees and of in-service training for persons already in the service.

The personnel department would also be concerned with stimulating health and safety measures in the plants and offices of the Commission; with housing, recreation, and related matters incident to employment; and with the determination of labor standards, including working rules, rates of pay for unclassified and special presonnel, and methods for the adjustment of grievances.

In addition to these conventional—and highly important—activities, the personnel department should be given the broad duties of leadership in promoting an essential development—procedures for systematic cooperation between employees, their organizations, and representatives and the supervisory and administrative staffs of the Commission. In this lies perhaps the most significant opportunity for furthering in every phase the public purposes stated in the Atomic Energy Act.

Fortunately, the blueprints have already been drawn for the kind of comprehensive personnel policy suggested here. On the Canadian National Railways, the Tennessee Valley Authority, and the Bonneville Power Administration—all of them pioneers in the public administration of national resources—bold, constructive, and forehanded action has paved the way to new concepts of human relations in industrial enterprises. The lessons learned in these undertakings can be of the greatest value both in insuring against future deterioration of personnel relations and in assuring that the work of the Atomic Energy Commission will get under way with maximum efficiency.

The chief argument for an early and aggressive personnel program, however, is not the prevention of future difficulties or the selection of a competent group of people. It is rather the inauguration of policies, standards, and methods which will build up to the highest possible level of organizational morale. It is definitely within the power of the Commission itself to shape the course of events toward this positive and eminently desirable goal.

In many respects the production of atomic energy offers an even more challenging vista than did the establishment of huge public power developments or the operation of a railroad covering half a continent. This fact should be seized upon as the basis for creating within the organization under the Atomic Energy Commission a spirit of cooperative endeavor in a vital mission. Such an atmosphere will do more than any other single thing to guarantee the full realization of the potentialities for national and international welfare in the release of atomic energy.

Our Publication Policy as Seen from Abroad

. . . *Victor F. Weisskopf*

The situation among scientists outside the United States seems to be very critical. From my contacts with people from outside, I am left with the impression that the foreign scientists believe that American scientists are completely enslaved by the American Government and by the armed forces. This is primarily due to the misconceptions created abroad by the recent Army and Navy research contracts. Foreign scientists believe that the purpose of these contracts is to force our scientists into work on weapon development.

They admit that we have the good will to improve the situation, but they think we are completely powerless. Therefore, they, for the most part, discount any help from our side; they believe they will never get any information of a scientific nature out of this country even on subjects that have been declassified. Perhaps a characteristic example of their attitude can be found in a recent issue of the British Medical Bulletin which contains a great deal of information on radiation problems. This Bulletin lists its distribution sources from all over the world, but does not mention any in the United States.

Much could be done to improve this situation; for example, by accelerating the declassification of declassifiable material and by sending this material as soon as possible to foreign scientists. There is a danger of creating a bloc of all foreign scientists against us, wherein they develop their own ideas and their own plans, discounting any collaboration with America. This attitude is understandable in view of the present state of world affairs. However, if it is not changed, it will be very harmful for any international understanding.

The Scientists' Role in International Relations

. . . . . H. A. Kramers

The life of us human beings on this earth is a complicated affair. I suppose you are all aware of this. I suppose also that many of you are worried by this complexity, at any rate by certain aspects of it. Why are you worried? There may be different reasons. Maybe it is your personal affairs and those of your family which need your attention: they confront you with a task which is difficult to fulfill since the problems are *so* complicated. You do not know what to do about them and at the same time something must be done. That's what worries you.

Another type of worries take their origin in the complexity of affairs which pertain to larger groups of people. If you are a university man it is your job, your duty, to attend to such affairs. You are expected to take decisions, to take action with regard to your students, to your collaborators, to your laboratory. Some of you will have a natural, or an acquired gift to tackle the difficulties which arise here, and your worries need not be overwhelming; others will constantly suffer.

Finally, let us think of human affairs, the complexity of which worries you although nobody asks you to worry about them. Social affairs of wider scope may belong to this category; questions of the administration and government of your town, of your state, of your country, and last but not least: international affairs. There may be things which you disapprove of and about which you think something ought to be done; people, who in part are responsible for the situation and who are in a position to take action do not take action or take action in a way you think is bad. You might belong to those, who—gifted with true or false insight—know at once what ought to be done about such affairs, but you might also be one of those, who have tried to analyse the situation in—say, a scientific way and who thereby have realized its complexity. Then you may start to worry, in a way—perhaps—which leaves you no peace and you may well become jealous of those who disregard the complexity and admire their courage when they take action in the way which Alexander tackled the Gordian knot. But all of you will realize that admiring Alexander does not mean that you approve of him.

Now the Gordian knot was not a social, a human affair. The complexity of affairs of the latter kind derives a good deal from the amazing, the queer and the discouraging characteristics of man himself. From his intelligence and his lack of intelligence, from his morale and from his lack of morale, from his egotism and from his devotion to others, from his desire for war and his desire for peace, from his lust to rule others and his ability or incompetence to rule others.

Compare this complexity with the complications which the *scientist* meets in his own dear field. They are often so bad that he is inclined to omit the adjective "dear." His passion to hunt in his field has perhaps in the beginning been urged by some kind of love, but look how often this love turns to anger. He is like the hunter, who gets very angry at the lion he loves to hunt. But anyhow, in all his worries, the only personality, the only psychology he has to cope with is his own; the object with which he deals is inhuman, has no good-will or malice, even if he often may be inclined to think of the sphinx of nature, with whom he is wrestling, as a fellow-being, the relations with which are constantly changing. He pats her and she scratches him; he scolds her and, look, how nice she then often can be. The better he knows how to handle her, the less he understands her, in accordance with what the French poet, Henri de Reguier, said about women in general.

But let us leave this personification of nature out of the picture. Let us come to the theme which has brought us together this evening—the scientists' role in international relations. You will have felt in what spirit, and perhaps also in what mood, I have tried to approach this theme. Here we have the *scientist*, who is accustomed to cope with inhuman affairs of extreme complexity, and who starts to worry about international relations, the complexity of which is so greatly enhanced by its human aspects.

Two questions arise. The first is: why are there, in these times, more and more scientists who really are assailed by such worries? And the second is: what can he do and what shall he do about it? And what hopes may he cherish?

As regards the first question, you get the answer by considering what science has been and what scientists have been in the course of the history of civilization and to what point we have come now in the course of the evolution of science.

In old days, say two or three hundred years ago, scientists worked as separate individuals who collaborated through their letters, through their books and through their occasional meetings, small ants in the ant-heap of human affairs, whose direct spheres of activity were small, however big the final outcome of their work might be for human civilization. In their work they hardly needed to pay attention to the eventual outcome, and they had no more reason than any other citizen to worry particularly about national or international affairs. Christian Huygens, the Dutch physicist of the 17th century, paid hardly any attention to national or international relations. He felt himself as naturally belonging to the international brotherhood of learned men, which held an attitude of more or less outspoken contempt with regard to matters political. When Louis XIV in 1672 made an agressive war on Holland, he stayed peacefully in Paris. No need for him to pay attention to those wars: he was too busy anyhow. Simon Stevin, of Bruges, who lived half a century before Huygens, was much more what we would call now, socially minded, but he was so by inclination. He helped his master, Maurice of Orange, to build fortifications; he also wrote a treatise on house planning from which his worrying about social conditions becomes clear. In his case it was not the outer circumstances which dragged him, as a scientist, to the scene of human affairs—and the technical aspect of these affairs was always foremost in his mind.

In our times, however, things are so different. As one of my colleagues in Leyden expressed it, science has more and more been making toys—toys, however, which they are not allowed to play with themselves; their big brothers, that is, the rulers of this world, have appropriated these toys, and used them for all kinds of purposes, and many of these purposes are not so very nice. We scientists have become very conscious of the fact that our efforts eventually will lead to results which are apt to modify the living conditions of mankind on our earth. Seeing this, our social conscience is awakened, and we hope that these modifications will be for the good and not for the worst. My Leyden colleagues expressed it like this: we wish that it be left to us to play with the toys we made ourselves. This is certainly an over-simplification of the problem. We do not want, we have no time, most of us at any rate, to play ourselves, but we feel a certain responsibility and want to see that the toys we made ourselves are used in the right way, nationally and internationally.

And here we become confronted with

An address delivered at the Bicentennial Celebration of Princeton University.

the second of the two questions mentioned above. What can we do and what shall we do, and what hope can we cherish about the outcome of our activities? Now some us may beforehand be conscious of our incompetence regarding the task which dawns before us, or we may be cowards or egotists and shut ourselves up in our rooms as well as we can. Others among us may gird their swords and run to partake in the battle. And these will soon see, or ought to see, with their scientifically trained minds, the complexity of the problems before them.

This complexity I have mentioned at the beginning of this talk. There I pointed out how this complexity was due in large part to the human element in group relations, especially in affairs of international scope. We poor scientists who want to take part in the battle will have to understand human behavior, and woe to us if the natural gift for doing so is lacking in us. But if we have it, what can we do and what shall we do?

I hope you do not expect a definite answer from me tonight. I will only try to give two indications of the way to follow. The first is that we should take advantage of everything which the occupation with our own science has taught us. That is, we should study with patience all facts, turn them over and over, and we should not scorn or overlook *details* since we know that from the consideration of details the solution of the big problem often has emerged. On the other hand, patience should not mean indefinite postponement of decisions and actions. There is no textbook which tells us how to find the right balance between thinking and acting; he who has the grace will do it well. This well-balanced scientific attitude may prove, *must* prove, beneficial in all human affairs, in all things political.

The second indication is the following. Science is, as I said above, rather inhuman; international relations are contaminated by their human aspects and therefore so much more complex. But look here: are things human so much worse than things inhuman? Has not the word "inhuman" the connection of meaning something less desirable than the word "human"? In human relations we are no longer alone with the riddle of our own personality. When we are two we may achieve much more than when we are alone, and when we are many, how big is the promise that groups of people will find each other and work together at a problem, which no single man can solve? In human nature lies our worst enemy, but at the same time, it holds out the promise for that friendship which means collaboration and achievements for the future of mankind.

The UN Atomic Energy Commission

The informal meetings of the Committee 2 of the Atomic Energy Commission continued throughout November, but little transpired as to the subjects discussed. To the report on the first five such meetings, printed in the last issue, it may be added that on October 22, **Dr. G. M. Briggs** (Australia) gave an outline of the occurrence and working of thorium-bearing sands in Australia, and **Prof. Alexandrev** (U.S.S.R.) discussed thorium as by-product of the mining of gold and other minerals in U.S.S.R. It was generally agreed that the wide occurrence of thorium deposits, for instance, monazite sands, on the ocean beaches, and the small scale of mining operations involved, make it more difficult to control thorium than uranium.

In the same meeting, the Secretariat was requested to formulate a draft statement of the problems involved in the setting up of controls over the mining of uranium and thorium so as to prevent diversion of raw materials at the mining stage.

In the seventh informal meeting, on November 4, a general account of the control of chemical and metallurgical processes in industry, was given by **T. H. Critchett** (Electro Metallurgical Company). A working paper on control of thorium submitted by the U. S. Delegation on October 31, was considered, as well as a revised draft of the working paper on the control at uranium mines and mills, prepared by the Secretariat on October 28.

* * *

On November 13, a plenary meeting of the Atomic Energy Commission was held for the first time in four months, to hear a report by the chairman, Mohamed Bey Khalifa (Egypt). He criticized the delays and wrangles in the Commission, and declared the peoples of the entire world were waiting upon the outcome of the Commission's work. He said he believed that during his stewardship "some real progress" had been made toward the Commission's goal and that "in this all the members have cooperated heartily and willingly."

The report asserted that the Commission's Scientific and Technical Sub-committee had reported that from the technological point of view, "control of atomic energy was feasible," and had indicated the "danger points" at which such control should be applied.

"There still remain, of course, major political problems," the report said. It is time that we deal with them."

Colonel Khalifa took note of a "few public expressions of impatience" at the failure of the Commission to reach a final and unanimous conclusion, and reminded the membership that "We cannot leave out of account the words in our mandate that the Commission proceed 'with the utmost dispatch.'"

The report closed with suggestions (1) that the Atomic Energy Commission submit to the Security Council by Dec. 31 a report of its proceedings, findings and recommendations, based upon its deliberations to date; and (2) that the General Assembly Committee 2 (Economic and Financial) be directed to offer drafts for such a report, or parts of it, from time to time, to the Atomic Energy Commission for its consideration and action, all drafts to be completed by Dec. 20.

Bernard M. Baruch, United States delegate to the Commission, expressed "full agreement" with the report and moved that the suggestions be adopted.

Capt. Alvaro Alberto of Brazil and Gen. A. G. L. McNaughton of Canada spoke in behalf of the report and its suggestions. General McNaughton urged that before the change of membership at the end of the year, when three new countries take office, the Commission should convey to a public "naturally concerned" a report on the ground that had been covered.

S. P. Alexandrov, who spoke for the Soviet Union, pointed out that the report had been made available only a few minutes before the session convened, and he said that the time factor raised a problem; that the matter called for preliminary study and that, consequently, he was not in a position to vote for or against.

The French representative, Alexandre Parodi, opposed the Russian interpretation of the time limit in the suggestions, declaring that it did not constitute an "imperative or strict time limit" on the work of the committee in seeking atomic energy control, but involved only the report on recommendations contained in the suggestions of Colonel Khalifa.

M. Parodi also remarked that there were proposals by the United States and Soviet Governments on total disarmament before the General Assembly and that if the Atomic Energy Commission hastened its work, it would facilitate the problems of the Assembly on the disarmament question.

The report and the suggestion were then adopted by unanimous vote, with the U.S.S.R. and Poland abstaining.

The Present Status of Declassification . . . .

In the November issue of the "Bulletin of the Atomic Scientists," we inaugurated a program designed to shed light on the policies of the Manhattan Engineer District with regard to declassification and dissemination of technical information gathered during the war. This program began wth the publication of an outline of the current MED procedures, written at the request of the "Bulletin," by Lt. Col. W. S. Hutchinson, Declassification Officer for the MED.

Our efforts to clarify this problem are continued in this issue. The basic principles that should guide the dissemination of such information are discussed both editorially and in a letter by Prof. Weisskopf.

* * *

Declassification has been in operation for over 6 months. At the present writing, about 600 documents have been classified. However, up to Nov. 28 not even a partial list of titles of these declassified documents had been distributed to scientists, either American or foreign, outside the Manhattan Project.

That small fraction of our scientists within the Project have not fared much better. A list of about 80 titles, dated July 15, and marked "For Distribution Within the Manhattan Project Only" was issued in October to key project personnel. A second list of about 100 titles, dated August 1, and similarly limited in its distribution, was scheduled for the first week in December.

In view of this unsatisfactory situation a number of prominent scientists have urged that the "Bulletin" publish a complete list of the declassified documents. During the last days of November a series of discussions with the Declassification authorities has brought about some clarification of the issues. As a result the "Bulletin" presents below the titles contained in the July 15 and Aug. 1 lists and we plan to publish the additional lists as they are made available.

* * *

A great deal of confusion still exists regarding the methods of making copies of the declassified documents themselves available to both those inside and outside of the Manhattan project.

Some of the sources of this confusion are obvious. Instead of listing them we here confine ourselves to a recital of the sorry state of the present situation and note that authorities have assured us that the distribution of declassified documents will show improvement in the near future. We will report these long-overdue actions as they become effective.

PROJECT DISTRIBUTION:

According to policy of the Research Division of the MED, as of Aug. 1, distribution within the Manhattan project of the documents listed below is to be made as follows:

"Copies of these documents will be distributed by the Information Branch, Research Division, Manhattan District, to every Project installation which normally receives project reports. Coordinating Organization Directors and Responsible Reviewers who do not have access to any Project information service may obtain copies on request. Since deletions in the original documents may have been made by the originating institutions before submission for declassification, this publication (the Aug. 1st list of Declassified Documents) does not constitute authority for declassification of classified copies of documents which may bear the same title and report number and which may have been written by the same authors. The originating institution, only, may use the declassified document received from the Declassification and Publications Branch as authority for the declassification of such classified copies of the original document as contain no Manhattan Project scientific and technical information in excess of that contained in the declassified document. The originating institution is responsible for notifying all recipient institutions or individuals of the declassification of such classified copies as the originating institution has distributed. Classified copies which must remain classified because of deletions made before submission for declassification may be retained in the recipient's file as classified documents or they may be returned to the originating institution or destroyed in accordance with the provisions of A.R. 380-5. Furthermore, this list does not constitute authority for declassification and release of items of equipment or material mentioned in the documents (unless specifically written to declassify the items), references used by the author, or similar papers."

* * *

PUBLIC DISTRIBUTION:

Individuals or organizations not presently under contract with the Manhattan project may request copies of the documents listed below as follows:

1. Requests for copies of the documents listed under A should be addressed to the Offices of Technical Services, Department of Commerce, Washington, D. C.

   It should be noted that documents which have been sent to the Offices of Technical Services, Department of Commerce, were to have been included in the Department's weekly publication, "Bibliography of Scientific and Industrial Reports." These documents then were to have been made available for public distribution by the same office in the form of microfilm or photostats.

   However, examination of this publication shows that less than twenty of the documents listed in Part A have appeared to date. Furthermore, all of these appeared in the Aug. 9th issue of the publication; none in the issues from Aug 9-Nov. 8. Finally, attention should be called to the joker: "...the Department of Commerce will withhold distribution through its channels until publication has been accomplished on those documents to be published in the standard technical journals."

   Clearly the original plan to issue declassified documents to the public through the medium of the OTS of the Department of Commerce has not been a signal success. It is equally obvious that if the OTS has merely become another repository for Manhattan Project declassified documents instead of a distribution center nothing is gained by concealing this fact.

2. Requests for documents listed under B should be referred to the authors concerned, since these documents were withheld from the Department of Commerce.

* * *

Unless it is realized that the documents listed below vary widely in character and quality the titles alone may be misleading. The documents were written originally for such disparate purposes as: oral presentation before both popular and scientific groups; publication in newspapers, popular texts, scientific journals and the projected Manhattan Project Technical Series; industrial and manufacturing specifications.

Although there is no single source for the public dissemination of all declassified documents, the standard scientific journals have, in the past few months been publishing a number of these documents. We refer our readers to recent issues of the Physical Review, Journal of the American Chemical Society, Review of Scientific Instruments, Science, Chemical and Engineering News, etc. Thus documents declassified for oral presentation before the American Physical Society are summarized in brief abstracts in Phys. Rev. v. 70, 99 and 448, 1946. ***H. H. G.***

A List of Manhattan Project Declassified Documents

PART A

Mass Spectrometer for Leak Detection—T. A. Abbott, A. Hustralid, A. O. Nier, C. M. Stevens.

The Neutron-Proton and Neutron-Carbon Scattering Cross Sections for Fast Neutrons—Carl L. Bailey, W. E. Bennett, Thor Bergstrahl, Richard G. Nuchols, H. T. Richards, John H. Williams.

Thick Target Yields with Deuteron-Proton Reactions—E. C. Barker.

On the Disintegration of Nitrogen by Fast Neutrons—H. H. Barschall, M. E. Battat.

Scattering of Fast Neutrons by Boron—H. H. Barschall, M. E. Battat, W. C. Bright.

Neutrons from C^{12}+D—W. E. Bennett, H. T. Richards.

On the Existence of a Resonance Absorption of Neutrons in Graphite—S. Bernstein.

Atoms and Nuclei—H. A. Bethe.

The Theory of the Synchrotron—D. Bohm, L. Foldy.

Fissionability Studies—L. B. Borst, J. J. Floyd.

Diffraction of Neutrons—L. B. Borst, A. J. Ulrich, C. L. Osborne, B. Hasbrouck.

Energies of the Delayed Neutrons from U235 Fission Products—M. Burgy, L. A. Pardue, H. B. Willard, E. O. Wollen.

Radiation Chemistry—Milton Burton.

Pile-Produced Radioisotopes of Half-Life longer than 12 Hours—E. Waldo Cohn.

Radiochemistry and the Fission Products—C. D. Coryell.

A Graphical Method for Determining Particle Trajectories—E. C. Crittenden, Jr., W. E. Parkins.

Methods for Betatron or Synchrotoron Beam Removal—E. C. Crittenden, Jr., W. E. Parkins.

Proposed Neutron Spectrometer in the 10-1000 Kev Range—B. T. Feld.

The Multi-Channel Pulse Analyzer—A. Ghiorso, B. Weissbourd, H. Robinson.

A Method for Measuring Half-Lives—A. Graves, R. Walker.

Assignment of Mass to 46 hr. Samarium and 9.2 hr. Europium by a Mass Spectrograph—R. J. Hayden, M. G. Inghram.

Higinbotham Scale of 64, Mark 5, Model 3—W. Higinbotham.

Radiative Capture Cross-Section for Fast Neutrons—D. J. Hughes.

An Apparatus for Measuring Joule-Thomson Effects in Gases by Direct Expansion Through a Valve—H. L. Johnston.

Joule-Thomson Effects in Hydrogen at Liquid Air and at Room Temperature—H. L. Johnston, Irving I. Benzman, C. B. Hood.

Joule-Thomson Effects in Deuterium at Liquid Air and at Room Temperatures—H. L. Johnston, C. A. Swanson, Henry E. Wirth.

Counter for use in Scattering and Disintegration Experiments—P. G. Koontz, T. A. Hall.

Scattering of Fast Neutrons by Helium—P. G. Koontz, T. A. Hall.

Nucleonics and the Chemical Engineering Curriculum—M. C. Leverett.

Chemical Isolation of the 56 Second Bromine and the 23 Second Iodine Delayed Neutron Activities—J. S. Levinger, E. P. Meiners, M. B. Sampson, A. H. Snell.

Pile Kinetics—L. W. Nordheim.

Manufacture of Carbon 14 in the Chain-Reacting Pile—L. D. Norris, A. H. Snell, E. P. Meiners, L. Slotin.

The Total Scattering Cross-Sections of Deuterium and Oxygen for Fast Neutrons—R. G. Nuchols, Carl L. Bailey, W. E. Bennett, Thor Bergstrahl, H. T. Richards, J. H. Williams

Design of Dynamic Condenser Electrometers—H. Palevsky, R. K. Swank, R. Grenchik.

The Neutron Spectra of Po-B and Po-Be—I. H. Perlman, H. T. Richards, Lyda Speck.

Health-Physics Building Surveying at Clinton Laboratories—W. H. Ray.

Frequency Modulated Cyclotron—J. R. Richardson, K. R. MacKenzie, E. J. Lofgren, B. T. Wright.

Theory of Pile Control Rods—R. Scalettar, L. W. Nordheim.

Energy-Angle Distribution of Betatron Target Radiation—L. I. Schiff.

Mechanical Frequency Modulation System as Applied to the Cyclotron—F. H. Schmidt.

Design, Construction and Preliminary Tests of a Double-Focusing Mass Spectrograph—A. E. Shaw, W. Rall.

Manual for the Proportional Alpha Counter—J. A. Simpson, Jr.

The Chemical Significance of Modern Nuclear Science and Technology—A Symposium by Oak Ridge Scientists.

Radiation from Fission Products—Katherine Way, E. P. Wigner.

New Opportunities and New Responsibilities for Scientists—M. D. Whitaker.

Plans and Problems in Nuclear Research—F. Daniels.

The Total Cross-Sections of Carbon and Hydrogen for Neutrons of Energies from 35 to 490 Kev—D. H. Frisch.

New Developments in Vacuum Engineering—R. B. Jacobs, H. F. Zuhr.

Recording Mass Spectrometer for Process Analysis—A. O. Nier, T. A. Abbott, J. K. Pickard.

Regulated Supply—V. S. Allen

Linear Accelerator—L. W. Alvarez

A Semi-Quantitative Method for the Spectrographic Analysis of Small Samples of Powders—M. C. Bachelder.

Sensitivity of Proton-Recoil Ionization Chambers—H. H. Barschall.

The Crystal Structure of Polonium—W. H. Beamer, C. R. Maxwell.

Model 100 Delay Line Shaper—No designated author.

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Spiral Fission Chambers—W. C. Bright.

Theory of Neutron Counters Using Proton Recoils from Paraffin—K. M. Case.

Half-Life of Uranium 234—O. Chamberlain, D. Williams, P. Yuster.

Room Temperature Casting Resin for Mounting Metallographic Specimens—J. S. Church.

Derivation of Equations—W. E. Cohn.

Hydrogen Recoil Proportional Counter for Neutron Detection—J. H. Coon, R. A. Nobles.

Alloys of Gold and Beryllium—B. D. Cullity.

The Willgerodt Reaction—W. G. Dauben, J. C. Reid, P. E. Yankwich, M. Calvin.

The Multiple-Wire Proportional Counter—B. Diven, R. W. Thompson.

Half-Life of C^{14}—J. R. Dunning.

10 M.C. Wide Band Amplifier and Scope—W. C. Elmore.

Model 500 Amplifier—W. C. Elmore.

Pre-Amplifier-Model 500—W. C. Elmore.

Neutron Spectrum from a Cold Para-hydrogen Radiator—T. Hall, F. de Hoffmann.

Spin Dependent Part of the Neutron-Deuterium Cross Section—T. Hall, F. de Hoffmann.

1500 Volt R. F. Power Supply (Coil Data)—W. A. Hane.

1500 V. R. F. Power Supply—W. A. Hane.

R. F. High Voltage, Power Supply (Voltage Doubler Type)—W. A. Hane.

R.F. Coil for R.F. High Voltage Power Supply (Voltage Doubler Type)—W. A. Hane.

Flat Response Neutron Detector—A. O. Hanson.

Pulse Analyzer—1 Channel—W. Higinbotham.

Scale of 64 and Discriminator—Model 200—W. Higinbotham.

Scale of 64 with R.F. Power Supply—Model 400—W. Higinbotham.

Scaler Unit Circuit—W. Higinbotham.

Efficiencies of Neutron Counters Using Recoils of Protons in Argon and Xenon—J. O. Hirschfelder, J. L. Magee.

Ratio of 60 Pulse Generator Mark 21, Model 3A—W. P. Jesse.

Survey Instrument, Mark 1, Model 10, Zeuto—W. P. Jesse.

Survey Instrument, Mark 1, Model 21-A, Zeus—W. P. Jesse.

Metallographic Preparation Method for Tungsten Carbide—G. L. Kehl.

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Note on performance of an Experimental Spray Scrubber—R. Landau.

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Elastic Backscattering of d-d Neutrons—J. H. Manley, H. M. Agnew, H. H. Barschall, W. C. Bright, J. H. Coon, E. R. Graves, T. Jorgensen, B. Waldman.

Production and Isotopic Assignment of a 90 Day Activity in Element 43—E. E. Motta, G. E. Boyd, A. R. Brosi.

Absorption of Slow Neutrons by Cd^{113}—B. J. Moyer, B. Peters, F. H. Schmidt.

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Counting Rate Meter—Model 200—M. Sands.

Counting Rate Meter—Model 100—M. Sands.

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Model 100 Amplifier—M. Sands.

Model 100 Precision Pulser—M. Sands.

Oscillograph Circuit—M. Sands.

Stopping Power of Various Substances for Fission Fragments—E. Segre, C. Wiegand.

Amplifier, Preamplifier—H. Staub.

Discriminator-Pulse Generator—H. Staub.

Double Scope Supply—H. Staub.

MW Counter (Drawings 1A to 6A)—H. Staub.

Step Calibrator—H. Staub.

Mass-Assignment of 2.6 h Ni^{65}—J. A. Swartout, G. E. Boyd.

Beta Rays from H^3—R. J. Watts, D. Williams.

PART B

Production of Low Energy Neutrons by Filtering Through Graphite—H. L. Anderson, E. Fermi, L. Marshall.

Phase of Neutron Scattering—E. Fermi, L. Marshall.

Reflection of Neutrons on Mirrors—E. Fermi, W. H. Zinn.

The Decay of Cb^{94} (6.6 min.)—M. Goldhaber, W. J. Sturm.

A Critical Survey of Neutron Cross Sections—H. H. Goldsmith.

Neutron Cross Sections of the Elements—H. H. Goldsmith, H. W. Ibser.

Mass Spectrometric Observation of C^{14}—M. G. Inghram.

Neutron Absorbing Isotopes in Gadolinium and Samarium—R. E. Lapp, J. R. VanHorn, A. J. Dempster.

The Preparation of Certain Halohydrocarbons—E. T. McBee.

Recording Ionization Chamber for Traces of Radioactive Gases—A. O. Nier, C. M. Stevens, T. A. Abbott, J. K. Pickard.

Mass Assignments of Some Radioactive Isotopes of Pd and Ir—Wilfrid Rall.

Studies of Neutron Resonances with a Crystal Spectrometer—W. J. Sturm, S. Turkel.

Theory of Heat and Mass Transfer in Batch Condensation of Solids—W. I. Thompson.

Crystal Structure Studies of Plutonium and Neptunium Compounds—W. H. Zachariasen.

The Bragg Reflection of Neutrons by a Single Crystal—W. H. Zinn.

Magnetic Gear for Torque Transfer to an Enclosed System—T. A. Abbott, J. K. Pickard.

The Role of the Johns Hopkins University in the Development of the Atomic Bomb—W. B. Burford III.

Photographs and feature article—*(Chicago Tribune)*.

Small Homogeneous Reactor at Los Alamos—"Water Boiler."—R. F. Christy.

Characteristics of Mixing and the Dilution of Waste Stack Gases in the Atmosphere—Phil Church, C. A. Gosline, Jr.

Elementary Theory of the Pile—E. Fermi.

Direct Mass Assignments of 55 Day Strontium and 57 Day Yttrium—L. G. Lewis, R. J. Hayden.

A Mass Spectrograph for the Analysis of Fission Product Mixtures—L. G. Lewis, R. J. Hayden.

Mass Spectrographic Identification of Active Isotopes Contained in Three Fission Product Mixtures—L. G. Lewis, R. J. Hayden.

Total Cross-Sections of Various Materials for Indium Resonance Neutrons—John Marshall.

Beneficial Isotopes Available from Atom Bomb Project—News Release and Photographs—G. O. Robinson, J. E. McKee, P. C. Aebersold.

A Precision Alpha Proportional Counter—J. A. Simpson, Jr.

Pile Perturbation Theory—Harry Soodak.

Calculation of Critical Size of Heterogenous Slow Neutron Chain Reactor—A. M. Weinberg.

A General Account of the Work of the Theoretical Physics Section in the Plutonium Project—E. P. Wigner.

The Preparation of Polyperfluorovinyl-chloride—E. A. Belmore, W. M. Ewalt, R. L. Murray.

Excitation of Plasma Oscillations—D .Bohm.

Resistance of Materials to Fluorine and Hydrogen Fluoride—M. H. Brown.

Carcinogenic Action of Some Substances which may be a Problem in Certain Future Industries—A. M. Brues, H. Lisco, M. Finkel.

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Technological Control of Atomic Energy Activities

Report Based on Studies by American Scientists —transmitted to the UN Atomic Energy Commission by the US Delegation

This report is the outcome of a number of studies begun almost a year ago.

Our readers will recall that the early issues of the Bulletin featured a series of articles treating many of the topics in the present report.

Further, it should be noted that the Federation of Atomic Scientists (predecessor of the Federation of American Scientists) instituted a classified study of the problem at the request of the McMahon Committee. This study was conducted by members of the FAS who were expert on particular phases of the various production methods.

The report published below is a declassified version of studies then conducted by two committees appointed by General Groves. (The material compiled by the FAS group was, of course, made available to these committees.)

The members of the two committees were:

M. Benedict (Chairman), L. W. Alvarez, L. A. Bliss, S. G. English, A. B. Kinzell, P. Morrison, F. H. English, C. Starr, W. J. Williams.

CHAPTER 1
INTRODUCTION

PURPOSE OF REPORT

The terms of reference of the United Nations Atomic Energy Commission direct it, in part, to make specific proposals:

(1) "For control of atomic energy to the extent necessary to ensure its use only for peaceful purposes;"

(2) "For effective safeguards by way of inspection and other means to protect complying States against the hazards of violations and evasions" of agreements concerning the use of atomic energy.

This report outlines measures of technological control designed to detect violations and evasions of atomic energy agreements without interfering unnecessarily with the peaceful uses of atomic energy. The necessity of preventing violations and evasions may, in some cases, introduce certain complications in the full exploitation of atomic energy for peaceful purposes.

It is essential to note that this report is concerned with technological control of atomic energy and not with political and military aspects of control. The objectives of technological control are to prevent, so far as possible by technical means, and to detect any violations of an agreement not to produce atomic weapons. Technological control should be designed to guard against any nation's securing a military advantage with respect to atomic weapons. The detection of violations would provide an immediate, clearcut warning of any step that might lead to an atomic war. The function of the technologist is to detect such activity when it starts; it is the statesman who must prevent its continuation.

It is difficult to define the amount of activity in the illicit production of atomic weapons which is significant. The illicit construction of a single atomic bomb by means of a decade of successful evasion would not provide an overwhelming advantage, if it can be assumed that it would take another decade to produce a second bomb. But the secret production of one bomb per year would create a definite danger, and the secret production of five or more per year would be disastrous. This report asumes arbitrarily that the minimum unit of non-compliance is the secret production of one atomic bomb per year or of a total of five bombs over any period of time.

FORMS OF EVASION OF TECHNOLOGICAL CONTROL

Evasion of technological control may take the following forms:

(1) Diversion of materials.
(2) Seizure of facilities.
(3) Concealment of operations.
(4) Any combination of the above.

Diversion of Materials

The peaceful use of atomic energy, which should be encouraged, involves the use of the same key raw materials and fissionable materials which are used in atomic weapons; the diversion of these materials to illicit weapon manufacture must be prevented. Fissionable materials which might be diverted would still have to undergo further processing before being fabricated into weapons, but they would already have been through some of the most difficult and conspicuous operations. For this reason, the most stringent control of these materials is particularly important. Denaturing keeps certain materials from being immediately suitable for easy weapon manufacture; it is important not to overestimate the degree of protection thereby provided, as has sometimes been done.*

Seizure of Facilities

Any atomic energy installation devoted to peaceful use is liable to seizure by any nation which decides to violate its agreement openly. Hazard is inherent both in the productive capacity of the facilities themselves and in the stocks of raw materials or partially finished products which must, to some extent, be associated with such facilities. The hazard can be minimized by limiting the type and capacity of installations and the amount and nature of materials which are processed and stored. The use of denatured material, for instance, somewhat diminishes the hazard. Technological control should ensure that all facilities are of such a type and so located that their seizure would confer the least military advantage on the outlaw nation.

Concealment

Once the production of atomic weapons has been prohibited under the terms of a treaty, the danger will still exist that they can be manufacured in hidden or disguised facilities. To do this, it would be necessary to secure fissionable material through diversion or to construct and operate clandestine facilities for production of fissionable material. In the latter case, illegal methods of obtaining raw materials at some stage would also be necessary. Technological control should detect concealed facilities of these types and discourage their construction and operation because of the likelihood of their being detected.

THE ROLE OF THE ATOMIC DEVELOPMENT AUTHORITY IN TECHNOLOGICAL CONTROL

The United States Representative proposed to the United Nations Atomic Energy Commission on June 14, 1946, that an Atomic Development Authority be created to conduct technological control as well as to foster the beneficial uses of atomic energy. The existence of such an Atomic Development Authority is assumed throughout the report; for brevity it will be referred to as the "Authority." This organization would have to be international in scope, enjoying the real confidence of all nations and operating under a satisfactory grant of rights from the various states. It is not within the province of this report to consider the relations of the Authority to the existing organs of the United Nations. The report has to do with the functions of such an Authority after it is in full operation and is not concerned with the transition period during which the Authority would be set up and would gradually assume these functions.

Because of the dual purpose of the Authority, to promote the beneficial uses of atomic energy while preventing its use as a weapon, it is natural to use the terms "authorized" and "unauthorized" operations. *Authorized* operations are those which have been made known to and permitted by the Authority and which are controlled by it through simple registration, licensing and inspection, supervision, or

*See chapter 2 for definition of "fissionable materials" and discussion of "denaturing."

management and operation, the form of control depending on the degree of danger inherent in the activity. All other operations in the field of atomic energy are regarded as illicit and potentially dangerous and are termed *unauthorized*. They will be unknown to the Authority until it detects them through one of the many diverse activities suggested for this purpose.

For the *control of authorized operations* and the *detection of unauthorized operations* a logical division of the activities of the Authority would be into three groups:

(1) Strict technological control of dangerous* materials and facilities so as to ensure their use for peaceful purposes only. Such control will include management and operation of dangerous facilities and custody of dangerous materials.

(2) Limited technological control of safe materials and facilities. This will include the registration, licensing, and inspection of safe facilities and the provision of safe materials under appropriate control.

(3) The detection of undeclared and therefore unauthorized activities which could lead to the production of atomic weapons.

It is the purpose of later sections of the report to detail by what measures and with what estimated success these very different forms of activity can be carried on.

It is certain that future advances in physical science and atomic energy technology will require modification of the details and possibly the character of control. The Authority must have at its disposal means for learning of developments while they are still in progress and must never become static. The control methods outlined in this report must therefore not be regarded as final, but as effective measures at the present stage of development only, and as a guide to what type of measures may be needed in the future. Accordingly, the Authority should be empowered to expand or modify its functions to meet new conditions as they arise.

CHAPTER 2
NATURE OF ATOMIC ENERGY ACTIVITIES

Technological control of atomic energy is rendered difficult by the similarity of the operations leading on the one hand to peaceful uses and on the other hand to production of atomic bombs. Control must take advantage of such differences as do exist in the operations leading to the two uses. This chapter describes the materials and operations involved in the utilization of atomic energy, with emphasis on those features which have a bearing on technological control.

BRIEF LISTING OF MATERIALS AND PROCESSES

Essential Materials

Present knowledge about atomic structure indicates that the number of isotopes that may be used as practicable sources of nuclear energy is very limited. Only one such material is found in nature, uranium-235. Another, which does not occur naturally, is plutonium-239, formed from uranium-238 through the absorption of neutrons. When sufficiently concentrated, these isotopes may be used either for atomic bombs or for power generation and other peaceful purposes; at low concentrations it is not practicable to use them for bombs, although they may still be used, perhaps less efficiently, for peaceful purposes. A possible third material is uranium-233 which can be made from thorium. Uranium-233 is a material that theoretically at least could be utilized either in the controlled operation of atomic energy reactors or for the production of bombs.

The general term "fissionable material" as used in this report applies to material containing the isotopes U-235, Pu-239, or U-233 in sufficient concentration to maintain a self-sustaining nuclear-fission chain reaction.

U-235 is present in natural uranium to the extent of 0.71%. This concentration is sufficiently high to permit the use of natural uranium in the generation of atomic power, but possibly less easily than if high concentrations of U-235 were available. Naturally occurring uranium does not contain a sufficient concentration of U-235 to permit its use in bombs.

Natural uranium is the only known element occurring in nature which can be used alone as a starting point for the release of atomic energy on the basis of present scientific knowledge. With natural uranium, Pu-239 can be synthesized; with natural uranium and thorium, U-233 can be synthesized. If the raw materials and all materials into which they are converted in the several processes leading to the release of atomic energy could be *completely* controlled, the restriction of atomic energy to peaceful uses could be assured.

Primary and Secondary Operations

In analyzing the technological control of atomic energy, a useful distinction can be made between processes leading to the release of atomic energy which are carried out solely with naturally occurring fissionable material and those which also make use of enriched or synthesized fissionable materials.

As indicated above, uranium is the only naturally occurring element now known which contains fissionable material. Any operation in which the only fissionable material supplied to the process is U-235 as it occurs in natural uranium is called a "primary operation". Examples of primary operations are the concentration of U-235 in natural uranium, the generation of atomic power from natural uranium, and the manufacture of Pu-239 from natural uranium.

Any operation which utilizes enriched or synthesized fissionable material is called a "secondary operation." The fissionable material may have been produced either in a primary operation or in another secondary operation. An example is a pile which consumes enriched U-235 or Pu-239 and which could be used for power generation or for synthesizing Pu-299 from U-238 or U-233 from thorium. Hence, both natural thorium and natural uranium, as well as enriched materials, are of significance in secondary operations.

Outline of Primary Operations

In this report, primary operations are taken to include those of mining, concentrating, and refining uranium ores and preparing uranium compounds, as well as the separation and production of fissionable material from natural uranium. Ores containing uranium are mined, and the uranium values are concentrated in mills and concentrators. Uranium concentrates from these operations are converted to commercial uranium compounds in refineries. These commercial compounds are further processed into feed materials for the plutonium-producing piles or the U-235 separation plants. The yield of fissionable isotopes that can be secured from these primary operations is very small. For example, even with complete recovery, the maximum possible yield of U-235 in an isotope separation plant would be only 0.71% of the natural uranium fed; of course the actual yield is less than this. Control of the large amount of natural uranium needed can therefore be an effective means of preventing the unauthorized production of fissionable isotopes in primary operations.

Outline of Secondary Operations

The possibility of secondary operations on a large scale has not yet been demonstrated. However, every effort will probably be made to render such operations technically feasible. Although secondary operations could be conducted with relatively small amounts of natural uranium compared to those in primary operations, it is important that they might require comparatively large investments of *enriched* U-235 or other fissionable material. To prevent diversion to unauthorized uses, very strict control of the fissionable material fed into secondary operations is required and equally strict control of any products from which fissionable material may be removed.

MINING AND CONCENTRATING OF URANIUM AND THORIUM

While the occurrence of uranium is fairly widespread, deposits of commercial importance have been operated in only a few localities in the past. The proposed use of this element in the peace-time development of atomic energy may change the criteria of commercial importance so that deposits in many localities will be worked in the future. Thorium deposits are much more plentiful than uranium deposits.

Geological Occurrence

Uranium is not a rare constituent of the earth's crust, but there are few worked deposits. The main published sources of uranium are the Belgian Congo and Canada, but uranium in less rich concentrations is known to exist in many other parts of the earth's surface. Until the discovery of the Canadian deposits, the deposits in the Belgian Congo were the main sources of the world's supply of uranium. The mines of Joachimsthal in Czechoslovakia, made famous as the source of the pitchblende from which Madame Curie first extracted radium, produce some uranium. Occurrences of thorium are reported substantially all over the world.

Mining

Prior to the war pitchblende was mined primarily for the radium content, and carnotite, another uranium-bearing ore, was mined primarily for the vanadium content. With the new demand for uranium,

* "Dangerous" and "safe" activities are distinguished in Chapter 3.

it may quite possibly become the main product in these cases. It is probable that the pre-war world production of thorium-bearing ore could be increased if a demand for the material were created.

Concentrating

Uranium and thorium ores are concentrated prior to chemical processing by normal ore dressing techniques. The degree of concentration effected depends on the initial content of the ore, the distance it must be shipped for chemical processing, and the method of transportation used.

Refining of Uranium

Commercial compounds of uranium are produced from pitchblende by successive processes. It is believed that the unaccounted-for losses in producing pitchblende concentrate, while small in percentage, are great enough to allow deliberate violators an opportunity for diversion in appreciable amounts.

It is important to realize that, until the radium and uranium have been separated, the mixture is radioactive, especially with respect to gamma rays. After the uranium is separated from the radium, it is less radioactive, giving off only alpha and beta rays.

While it appears feasible to attempt the rigorous control of refining operations in which uranium is one of the principal products, it would appear to be considerably more difficult to exercise the same degree of control over an operation in which the uranium is only a by-product of another operation. The full magnitude and importance of this phase of the control problem will be determined by the types of occurrence and the corresponding methods of recovery and will change as the methods improve. The accountability problem will be greater in such cases, and greater uncertainties as to the ultimate disposition of the uranium will exist.

Conversion of Commercial Uranium Compounds to Plant Feed Materials

It is believed that, under proper conditions of operation, unexplained losses in going from commercial uranium compounds to plant feed materials will be similar in amount to those met with in the concentration processes.

ISOTOPE SEPARATION OF URANIUM-235

Types of Processes for Concentrating U-235

The following four processes as well as quite possibly others could be used to concentrate U-235:

(1) Gaseous diffusion process.
(2) Electromagnetic process.
(3) Gas centrifuge process.
(4) Thermal diffusion process.

These four processes have previously been described by K. D. Nichols and J. R. Ruhoff in an article entitled, "Production and Utilization of Uranium-235 and Plutonium-239," in Volume I of *Scientific Information Transmitted to the United Nations Atomic Energy Commission by the United States Representative*, June 14, 1946.

It is probable that any plant for isotope separation which the Authority would undertake to control in the early steps of its existence would be of one of these four types. Other processes might be developed as a result of further study, and the control of isotope separation plants would require restudy if this were the case.

Operating Characteristics of Processes

The quality and quantity of the product of an isotope separation plant may be varied over wide ranges depending upon the plan of operation. In some isotope separation processes, there exists the possibility of changing the characteristics of the individual seperating elements so as to increase the product concentration at the expense of production rate. For other processes, however, there is an upper limit in a given plant to the product concentration, which cannot be exceeded as long as the plant structure is not changed or enriched feed is not used. This upper limit depends on the operating characteristics of the elements of the plant and on the number of these elements connected in series. If the upper limit to the product concentration were below that judged to constitute a military hazard and if the product concentration obtained while operating at efficient feed and product rates had beneficial applications, the plant would be useful for peacetime purposes without being of immediate military value after seizure, at least not until enriched feed were available or the plant altered. The length of time which would elapse before material suitable for bombs could be made in such an isotope separation plant depends on the amount of natural uranium and of enriched U-235 seized for use as feed, the inventory of uranium required for efficient plant operation, and the possibility of rearranging the plant to obtain more stages of separating elements in series. This last possibility varies greatly from one type of process to another.

Isotope separation plants might be dispersed in an attempt to avoid detection. Because of the parallel connection of elements in the electromagnetic, thermal diffusion and centrifuge processes, plants of these types could be subdivided into smaller, independently operated plants. The series connection of elements in the gaseous diffusion process renders more difficult the subdivision and dispersion of a plant of this type because of the complex schedule of large shipments of material of different concentrations between the subdivided plants.

It is possible to design an isotope separation plant which would take so long to reach a concentration of U-235 sufficiently high for bombs that its use for producing bomb material would be impractical. It is also possible to design a plant in which the amount of U-235 present in sufficient concentration for bombs would be too small to be of significance in bomb production; such a plant, if seized, would be of little hazard, provided that its supply of feed were cut off at the same time. However, the large inventory of uranium in a seized plant might be used in a plant of different design to produce bomb material.

Prevention of Diversion from Isotope Separation Plants

Isotope separation plants present some unique problems in preventing the diversion of valuable process materials. The small weight of product which is of military significance and the enormous extent of the plant make physical prevention of diversion, by inspection of all outgoing shipments and policing of the process area, of uncertain dependability. This places the principal burden of ensuring the detection of diversion on material accounting, through accurate weighing and analysis of all materials fed to the plant and removed from it and accurate inventories of material in process. However, the reliability of material accounting in U-235 isotope separation plants is appreciably lower than in conventional chemical plants. The primary reasons for this low precision are:

(1) The relatively inaccurate character of the assay for uranium isotopic content.
(2) The tremendous extent of these plants.
(3) The presence of undetectable but legitimate losses of uranium and U-235 within the process.

Detection of Unauthorized Isotope Separation Plants

The detection of unauthorized isotope separation plants is not difficult because of their large physical extent, the large staffs needed to operate them, the large amount of electric or steam power consumed by them, and the unique equipment employed in their construction and operation. Dispersion of the electromagnetic, thermal diffusion, or centrifuge plants might be attempted, to reduce the likelihood of their detection, but it is not certain that, as far as concealment is concerned, the reduction in size of these plants would offset the increase in their number.

Once inside the buildings of a suspected plant, one can relatively easily tell whether the separation of uranium isotopes by one of the four methods mentioned is going on, because of the unique character of the equipment and the ready identification of uranium compounds in process. There could be no confusion with ordinary peacetime installations. However, uranium isotope separation plants do not give off any unusual chemical or radioactive wastes nor do they emit readily detectable radiation. Consequently, it is necessary to have direct access to a plant to establish that it is in fact separating uranium isotopes.

NUCLEAR CHAIN REACTORS AND ASSOCIATED CHEMICAL PLANTS

Nature and Functions

The subject of nuclear chain reactors is by no means as simple as that of isotope separation plants. Isotope separation can be carried out, for example, by a single continuous process. The production of nuclear energy, on the other hand, usually involves at least two quite distinct types of operations: first, the chain reaction itself, which releases energy and which produces the neutrons capable of causing transmutation; and second, the chemical reworking of the highly radioactive materials upon their removal from the pile. Such reworking may be required simply for the purpose of extracting fissionable material after it has been produced by transmutation, or to maintain operation of the pile. The chemical processes are often

complicated and costly but, apart from the need for shielding personnel from the high radioactivity, they are parallel to the familiar operations of the inorganic chemical industry. The piles, however, are different from any existing industrial installations. More attention is therefore paid to the piles in the discussion which follows. It is to be remembered, however, that a large successful pile will require an associated chemical plant of comparable size and cost. For maximum convenience this plant will ordinarily be located near the pile, to avoid the hazardous transport of highly radioactive material.

The complexity of the whole problem, enforced by the many technical alternatives, is further increased by the diverse purposes for which chain reacting units may be operated. It will be useful to list these here:

(1) Research in the field of nuclear physics and chemistry.

(2) Production of radioactive materials and nuclear radiation in quantity for therapeutic and technical use.

(3) Production of fissionable material.

(4) Generation of heat, which may be used industrially or converted to electrical or mechanical power. This is what is spoken of as "atomic power."

It should be pointed out again that any operation of a nuclear chain reactor produces radiation (especially neutrons), radioactive materials, and heat. Which function the reactor serves is a matter of determining importance in its design, although any reactor may to some extent be made to perform all four of the listed functions. Industrially, it is likely that (3) and (4) especially will often go together.

Classification of Piles

As an indication of the various lines likely to be pursued in the design and operation of nuclear reactors, it is appropriate to point out the features which distinguish them.

Scale.—Perhaps the most important distinguishing feature of the pile is the scale on which it is to be operated. This does not mean the size of the nuclear reactor itself (which depends very little on the purpose of the operations, but mainly on the design of the structure), but the scale of the whole plant as an engineering unit. The best measure of this scale, which is reflected in physical size, required services, and cost, is the rate at which heat is developed, or the power of the pile unit. This heat may be allowed to flow out without special means of removal, it may be removed and thrown away by a cooling system, or it may be converted into electrical or mechanical energy by appropriate heat engines and electrical generators. The power developed (whether used or not) is proportional to the rate at which fission takes place. Therefore, by stating the power at which a chain reactor is operated, its scale and in many respects its functions are defined.

For research purposes, piles generating from only a few kilowatts up to a few thousand kilowatts will prove adequate for many years to come. Such installations range from laboratory size up to enterprises costing a few million dollars. They evidently can have little economic importance as producers of power. For ordinary domestic consumers in the United States, we may reckon about ⅓ kilowatt installed per capita. Thus, a reactor producing a thousand kilowatts of heat, or some 300 kilowatts of electrical power, could serve a small town of only 1,000 population. It would be a very large and useful installation for research purposes and would be a source of some fissionable material, but it would have negligible value for power production.

The production of radioactive materials and radiation for therapeutic purposes or for technical uses also requires only a modest amount of power. A pile which produces heat from fission at the rate of a few thousand kilowatts can produce very large amounts of radioactive substances. For instance, a properly designed pile at this power level could produce an activity of the very useful isotope phosphorus-32 equal over its short life to the activity of an enormous amount of radium. There are few foreseeable demands for radioactive substances which could not be met by such a comparatively small plant, which again would be of negligible importance as a source of power.

Economically significant development of power necessitates the operation of piles at such levels that important production, from a military standpoint, of fissionable material is possible. The amount of such material actually produced would depend on the design and operation of the pile. Heat would be developed at the rate of hundreds of thousands or even millions of kilowatts. The practical utilization of this heat is a technical problem still to be solved.

Types of Piles.—For every scale of developed power, it is possible to construct many types of reactors. The engineering features of all these pile types will be similar, determined primarily by the chosen power level, but the nuclear design and the economics of the materials supplied will of course be different. Various methods of operation are possible. For example, neutrons may be generated in excess of the number required to sustain the reaction. Such neutrons could be absorbed in foreign materials, or could be mainly absorbed in U-238 or in thorium, in which case fissionable material would be produced.

Features of Design.—Other bases for classifying piles are such design features as the way in which fissionable material is charged and withdrawn and the amount of fissionable material present in the pile during normal operation. If fissionable material is charged and withdrawn periodically, it could be sealed into individually identifiable containers which would be inserted into or removed from the pile only in the presence of the Authority's inspectors. All piles contain in their structure certain amounts of fissionable material. This is an especially important feature from the standpoint of control, since unauthorized closing down of the plant provides an immediate source of fissionable material, which might in some cases be directly usable in weapons. The amount of such material present will vary widely with the design of the pile and with operating procedure.

Prevention of Diversion from Piles and Associated Chemical Plants

Diversion of fissionable materials from a pile can be hindered by security measures designed to prevent theft, by material accounting, and by the fact that certain possible types of piles would cease to operate if material were diverted. Material accounting can be made very strict in piles where feed is charged periodically as slugs or lumps of metal into individual channels; the slugs would be counted and identified as they enter and leave. The fissionable material in a pile is extraordinarily difficult to remove, because it is highly radioactive and must be handled by remote control with great care.

Preventing theft of fissionable materials from the large and extensive chemical plant associated with a pile is much more difficult than from the relatively compact pile itself. After the slugs have been dissolved in the chemical plant, material accounting is less precise. However, diversion would be difficult here because of the great radioactivity of the material. At the end of the chemical process, when the material has been "decontaminated" or freed from radioactive fission products and concentrated in relatively small volume, there is the greatest danger of diversion from its authorized uses. Here the precision of material accounting can be raised somewhat.

The strictness of control required in a pile will depend upon the amount of fissionable material in the pile and the source of the fissionable feed material needed to maintain the reaction. If the Authority supplied all feed material, the stopping of operations after a very short time would be possible by shutting off the feed supply. More effective control of feed material would be possible if the chemical plant were operated separately from the pile. Fuel would then be supplied to the pile and after use in the pile would be returned to a chemical plant for reworking.

ATOMIC BOMBS

Atomic bombs have provided, up to the present, the principal justification for national support of the development of atomic energy. Their incredible destructive power has been widely described. At present, no peaceful economic use of the very violent explosion itself is known. It is probable that the atomic bomb can be used only for destruction. Therefore, the manufacture of atomic bombs should be prohibited under the terms of the treaty.

The cost of the development of the atomic bomb itself was small compared with the cost of the production plants required to furnish the fissionable material. Qualitatively, the operation of producing the atomic bomb was unique. A considerable fraction of the man-years of special research required by the entire project was devoted to the program. The quality and variety of the personnel were most unusual. It is, of course, true that much less research would be needed to repeat the effort if atomic weapon design became common knowledge. One of the necessary measures for the detection of bomb production or development would be to obtain information on the activities of scientific and technical personnel. The best control measures for the prevention of bomb manufacture are not those directed against bomb manufacture itself, but those intended to prevent the accumulation by any means of the essential fissionable materials.

DENATURING*

All atomic explosives are based on the raw materials uranium and thorium. In every case the usefulness of the material as an atomic explosive depends to some extent on different properties than those which determine its usefulness for peacetime application. The existence of these differences makes denaturing possible. In every case denaturing is accomplished by adding to the explosive an isotope, which has the same chemical properties. These isotopes cannot be separated by ordinary chemical means. The separation requires plants of the same general type as our plants at Oak Ridge, though not of the same magnitude. The construction of such plants and the use of such plants to process enough material for a significant number of atomic bombs would probably require not less than one nor more than three years. Even if such plants are in existence and ready to operate some months must elapse before bomb production is significant. But unless there is reasonable assurance that such plants do not exist it would be unwise to rely on denaturing to ensure an interval of as much as a year.

For the various atomic explosives the denaturant has a different effect on the explosive properties of the materials. In some cases denaturing will not completely preclude making atomic weapons, but will reduce their effectiveness by a large factor. The effect of the denaturant is also different in the peaceful application of the materials. Further technical information will be required, as will also a much more complete experience of the peacetime uses of atomic energy and its economics, before precise estimates of the value of denaturing can be formulated. Denaturing, though valuable in adding to the flexibility of a system of controls, cannot of itself eliminate the dangers of atomic warfare.

CHAPTER 3

DANGEROUS AND SAFE ACTIVITIES

The extent of control which the Authority would have to exercise over the various activities in the atomic energy field will depend upon the degree to which the particular activity could be used for unauthorized production of atomic bombs. For purposes of this report, activities will be described as "dangerous" and "safe." The atomic energy field will be construed to include all activities making use of uranium, thorium, fissionable materials, and certain radioactive isotopes produced in a pile.

DANGEROUS ACTIVITIES

It is not easy to make a clean-cut distinction between safe and dangerous activities. Any definition may be short lived since it will be predicated on the status of science and the development of processes as now known. In the future, new determinations and definitions will undoubtedly be required, and the Authority should be empowered to make these changes as they become necessary. However, an attempt to make a distinction between the safe and the dangerous can be useful without being completely sharp or fixed for all time.

Activities from which it would be possible to divert militarily significant amounts of fissionable material at any stage of processing from mine to bomb are considered to be dangerous. Certain other activities not involving large amounts of fissionable material are also considered dangerous if deemed primarily useful for the development and manufacture of atomic weapons. Dangerous activities should in every case be under complete control by the Authority and, with certain possible exceptions, should be managed and operated by the Authority.

At present the following activities are considered dangerous:

(1) The mining of uranium and thorium. (The type of control will depend on the character of the deposits.)

(2) The concentrating and refining of uranium or thorium ores or compounds, or of materials containing appreciable quantities of uranium or thorium as by-products.

(3) The production of chemical compounds of uranium and thorium.

(4) The storage and distribution of uranium and thorium in any form.

(5) Construction and operation of plants for separation of the isotopes of any element, if capable, when fed with natural uranium, of producing significant amounts of uranium enriched in U-235.

(6) Construction and operation of all piles capable of producing significant amounts of fissionable material.

(7) Construction and operation of chemical plants for the separation of pile products of a nature such as plutonium.

(8) Research on atomic weapons.

A key step in the control of dangerous activities is the control of mining, concentrating and refining of uranium and thorium bearing materials. The Authority must make a determination of the percentage of uranium or thorium content of raw material (i.e., the grade) below which complete control of the mines by the Authority is not warranted. This determination is particularly important in the case of mines which produce these materials as by-products, and would be influenced by the rate of production of the particular mines in question.

The construction and operation of isotope separation plants capable of producing a significant amount of U-235 in significant concentration is dangerous, because such material might be diverted for use in bombs. For such plants, the input of material is very large compared with the output and the possibilities of diversion are serious. A plant producing material of concentration less than that required for bombs is still dangerous if, in the event of seizure, the product of such a plant could be reprocessed to make bomb material.

The construction or operation of piles capable of producing significant amounts of fissionable material is dangerous because the material produced, after going through a chemical process, might be used in bombs. If the Authority furnishes feed materials for power piles, it may have to have large production piles with large inventories of material in process at all times. If nations were permitted to operate this type of pile, it would be possible over a period of time to divert significant quantities of material. Moreover, these piles would furnish a ready supply of bomb material if seized by any nation. If both a large pile and associated chemical plant were seized at the same time, together with normal supplies of materials at each plant, the nation making the seizure could soon have significant quantities of bomb material on hand.

The operation of chemical plants for the separation of fissionable material and fission products is listed as a dangerous activity due to the inventories in process at all times and the extreme difficulty of accounting for all the material. The processes involved are complex, with a great deal of piping of material from one place to another. Diversion of material in the last stages would be relatively easy if the plants were not operated by the Authority.

Manufacture of atomic bombs should be prohibited under the terms of the treaty, but the Authority would need to have complete information about the possibilities of bomb production. The maintenance of laboratories for research on this subject is clearly a dangerous activity and should only be undertaken by the Authority itself.

It can be seen from the foregoing examples that grave responsibility would be placed on the Authority for effective control of fissionable materials and facilities for their production, from the mine to final use. The Authority may not be able to prevent seizure of plants and stocks of fissionable material, but it should plan to minimize the military advantage to be gained by seizure. Careful scheduling, limited storage, and wide dispersion of plants and materials in many countries will be required.

Consideration should be given to certain activities which may well be *too dangerous* to be operated even by the Authority if reasonable security against surprise attack and reasonable delay between seizure of installations and bomb attack are to be assured. Manufacture of bombs is considered to be in this category. Other specific activities or combinations of activities should also be considered to determine whether they are too dangerous and should consequently be prohibited.

SAFE ACTIVITIES

Examples of safe activities are the use and production of fissionable materials in such small quantities as to insignificant for the production of bombs, the production of radioactive isotopes in specially designed piles, the use of radioactive isotopes, and research not concerned with bomb production. These activities must be licensed and inspected by the Authority.

One of the safest activities is the application of radioactive isotopes as tracers in scientific, medical, and technical studies. There may well be great advances in this field and there appears to be no reason for limiting this work.

It is easy to design small reactors for research purposes, which use denatured U-235 or plutonium as fuel. The design and inspection of these reactors should be the responsibility of the Authority. The reactors should be designed for operation at a power level so low as to be incapable of producing fissionable material in quantities of military

*This section is taken from a Press Release of the Department of State, dated April 9, 1946.

significance. Such a reactor could be safe and still provide neutron sources of great intensity. The material required in any one of these reactors would be of such small quantity and low quality as not to be significant for bomb production. However, some danger would attach to these reactors if they existed in large numbers.

An activity on the *borderline* of safe and dangerous is the high power level pile for the development of power for commercial use. Such a pile can be designed to use natural uranium, denatured U-235, or denatured plutonium as fuel, which would be consumed in the operation of the pile. In order to utilize the material contained in the pile for bomb purposes, it would be necessary to remove the material, decontaminate the fissionable material of any radioactive fission products, and separate it from the denaturant. With large power piles, the amounts of fissionable material in the feed, in the reactor itself, and in the used materials would be large. The Authority should have the responsibility for proper design and construction of such piles. Moreover, at the very least, close supervision by the Authority over their operation would be required to prevent diversion or improper operation. The degree of danger would of course depend on the number of such piles.

SUMMARY

Effective control of all atomic energy activities will be required if the nations of the world are to have any real degree of assurance against sudden atomic bomb attack. The processes are new and complex, and accurate inventories are difficult. Small diversion of fissionable materials in the last stages of production over a long period of time could be disastrous. Relatively small diversions anywhere along the line from mine to final product would be very dangerous if carried out over a long period of time. The longer the processes are in operation, the more alert the Authority will have to be to detect diversions. In the beginning the overall knowledge and know-how will be limited, but after a few years knowledge in this field will become widely diffused. The possibility of successful evasion of controls by a determined nation will then become greater unless the Authority constantly reexamines methods of control, stays in the lead of scientific knowledge and process development, and has been given and exercises sufficient power to broaden the scope of its activities to meet changing conditions.

CHAPTER 4
CONTROL OF DANGEROUS ACTIVITIES

INTRODUCTION

There are several considerations which point to the necessity in general for management and operation of dangerous activities by the Authority.

The primary reason for permitting dangerous activities at all is to develop those material benefits of atomic energy which could not be secured without those activities. Unless such dangerous activities are permitted under authorized auspices, the incentive to derive those benefits by unauthorized means might well be irresistible. Most of the activities leading to peaceful uses of atomic energy can also lead to military uses; only if these activities are carried on by an effective international organization can there be assurance that these activities are intended for peaceful purposes.

Another important reason for placing dangerous activities directly under the Authority is that the measures required for adequate control of the facilities involved are, in many cases, identical with the measures normally associated with sound management and operation of these facilities. Included, for example, are accounting for essential materials, taking of inventories, checking and improving analytical and assaying methods, establishing proper sampling procedures, controlling exposure time for uranium in piles, and calibrating and improving pile instruments. The reduction of unaccounted losses in isotope separation plants and the determination of the cause of changes in such losses are no less a part of efficient operation than a means of preventing diversion of fissionable materials.

In the constructive work of the Authority in promoting the beneficial uses of atomic energy through the operation of dangerous facilities, the Authority would be placed in intimate contact with the technical personnel in the scientific and industrial establishments of nations in which the dangerous facilities are located. This intimate contact would aid greatly in the detection of unauthorized undertakings. Also, by giving the Authority the right to conduct dangerous operations, we could insure that the Authority would achieve a preeminent position in regard to atomic energy technology. Its personnel would be better informed and better trained in the use of fissionable materials for any purpose than the personnel of individual nations. This preeminence would aid the Authority in anticipating technical methods of evading control and in determining how best to organize its detection activities.

Control of dangerous activities will have two principal aspects: control of essential materials and control of dangerous operations.

DISTRIBUTION AND STORAGE OF ESSENTIAL MATERIALS

Control of essential materials will take the form primarily of control over the distribution and storage of raw materials containing uranium or thorium and of fissionable materials obtained therefrom. It is necessary that the Authority control all uranium and thorium from the time it leaves the mine to final consumpion. Rigid control of these materials is a key step in the successful and safe operation of the whole atomic energy program.

Location of Stockpiles

As one important material-control measure, the Authority should design and locate its storage and production facilities in such a way that the stocks of raw material and fissionable material on hand in each are as low as is consistent with efficient operation and that the stocks are dispersed as widely as possible. Obviously, mining of uranium and thorium must be conducted where ore deposits are found, but stockpiles, warehouses, and processing plants for raw materials and fissionable materials should be so located that no one nation could derive a preponderant military advantage from the seizure of supplies of materials readily available to it.

Scheduling of Materials

The military value of raw materials and fissionable materials increases with each step in the processing from mining to consumption. The more highly refined the material, the more important it is to keep down the amount of such material on hand at any one time. A second important material-control measure which should be exercised by the Authority is the careful scheduling and coordination of all of its enterprises to produce refined fissionable material only as fast as it is consumed, thus keeping at a minimum the interplant stocks of idle fissionable material, which would constitute a potential military hazard.

Guarding Materials

A third important material-control measure would be to provide adequate guards to discourage and to detect diversion of raw materials and fissionable materials from warehouses, producing facilities, and shipments in transit. This last requirement means that guards of the Authority must be able to travel with all shipmens of these materials. After the materials have been enriched in U-235 or Pu-239, they should be guarded with greater care than the most precious stones. If the material is so enriched that it could readily be converted to bombs, it must be stored in extremely well protected vaults.

Material Accounting

A fourth material-control measure would be reliable accounting for raw materials and fissionable materials at all stages of processing and transfer from the mine to final use. The Authority must maintain accurate records of accountability for all shipments and all operations involving these materials. As the material becomes progressively more concentrated in uranium or thorium or progressively more enriched in U-235 or Pu-239, the reliability required of the material accounting becomes progressively greater. The Authority must weigh, sample, and analyze materials at all stages of the process from mining to consumption. In order that all groups may be kept alert and that confidence may be had concerning the dependability of the material accounting system, it is desirable that the personnel responsible for accounting and analysis at each plant work independently of the other operating personnel. All personnel, however, should be directly responsible to the Authority.

CONTROL OF DANGEROUS FACILITIES IN GENERAL

The ensuing pages are devoted to a discussion of the more involved subject of the control of dangerous producing facilities. In this section control measures generally applicable to all types of dangerous facilities are taken up. In later sections of this chapter, detailed methods of control for individual facilities are considered. It will be apparent from the discussion that control can best be secured by actual operation and management of most of these facilities.

Location and Capacity

Subject to general principles set forth in the treaty, the Authority must be able to specify the location and capacity of all dangerous facilities. This is necessary, in part, to prevent any of its plants from being located where control may be difficult. The main reason for

this requirement is, however, that producing facilities should be distributed in such a way that seizure of the facilities within any one country or group of countries would not give the aggressor a significant military advantage over other countries.

Process Design of Plants

The Authority must specify the types of processes to be used in all dangerous plants and the concentration and quantities of enriched materials to be handled in them. This is required to insure that the processes to be operated will be amenable to control. For example, the Authority should be able to limit the number of stages and other features of design in a gaseous diffusion process to those which could not under any practicable set of circumstances produce undenatured material suitable for direct use in bombs.

Structural Design and Inspection of Construction

Full control by the Authority over the structural design of proposed facilities is equally as important as control over process design. The structural design of these facilities should be such that they can be controlled to discover diversion. For instance, it should not be possible for hidden channels to be built into the plant, through which material might readily be diverted without detection. As another example, the charging face of a pile should be so designed that it can be readily kept under continuous observation and that any attempt to remove fissionable material can be immediately detected. Proper structural design alone facilitates material accounting by reducing the number of places at which samples need to be withdrawn while taking inventory. Control of structural design will also insure that the inventory of fissionable material in process may be so controlled as to amount, concentration, and distribution as to give the least possible advantage to a nation seizing a plant.

Specification of structural design by the Authority is of no value unless it is followed by inspection of construction at all stages, to insure that the approved design has in fact been followed. Representatives of the Authority must therefore supervise all stages of construction and be able to delay subsequent stages until satisfied that prior construction has been in accordance with the approved drawings.

Preparation of Operating Schedules

In order to control the total amount of essential material on hand at different degrees of concentration, the Authority must set operating schedules for all plants handling raw materials or fissionable materials. It must start with an estimate of the expected consumption during a given period and so adjust the production schedules of all its facilities that no shortages or excesses of partially refined materials can develop.

Gate Control

At mines and other producing facilities, the Authority must provide adequate inspection of all persons and shipments leaving the producing area, to prevent undetected movement of essential materials from the area. Gate control of this type is particularly effective in the case of radioactive materials and in the case of relatively unrefined materials where comparatively large amounts must be moved to be of military value. Detection of diversion of radioactive materials is more likely to be effective at piles and associated chemical plants and, possibly, at mines and ore concentrating plants, than at plants handling refined uranium or thorium, which are only weakly radioactive.

Control of Process Area

The Authority must also guard the portions of the facilities in which significant amounts of fissionable material are handled. For instance, it should provide continuous surveillance of those stages of a gaseous diffusion plant in which U-235, enriched to a significant degree, is treated. Similarly, for a chemical plant associated with a pile, the portion of the plant in which the valuable material has been largely freed of telltale radioactive contaminants should be heavily and continuously guarded.

Material Accounting

Material accounting is one of the most useful means of detecting diversion from certain types of producing facilities. Through material accounting a measurement can be made of the amount of material which has apparently disappeared from a particular producing facility during a particular period.

To account for fissionable material, the weight of all substances which are charged to or withdrawn from the facility during the period is determined and representative samples of these materials are analyzed for the content of fissionable isotopes. At the beginning and end of the period, an inventory is taken of materials in process and of their content of fissionable isotopes. From these measurements the net disappearance of fissionable material can be evaluated.

To carry out such material accounting the Authority would require a competent technical staff with facilities for analyzing fissionable materials and checking scales and other instruments and with access to all parts of producing facilities at any time in order to note shipments or take samples.

As has been pointed out, the reliability of material accounting and its suitability for detecting diversion differs greatly for the different types of facilities. For instance, it is of relatively little value in mines since it is almost impossible to take a sufficiently accurate inventory of ore reserves. On the other hand, in certain compact chemical processing operations, a very high degree of reliability can be placed on material accounting.

One limitation of material accounting should be noted. It is able to establish only that a certain amount of material is missing. It does not detect diversion at the instant of occurrence nor does it tell by what means loss or diversion has taken place. Moreover, since material accounting makes use of physical measurements, its reliability is limited by the precision to which these measurements can be made. For each type of productive operation, there is a percentage of the product rate within which material accounting is not sufficiently precise to establish that diversion has not occurred.

Access to Producing Facilities

Although complete access to producing facilities has been assumed in the preceding discussion, it is so important that it may be restated. In all dangerous activities, the Authority must have immediate access to all parts of the facility and to all records relating to its construction and operation and must be able to consult freely with all operating personnel.

Conclusion

From the foregoing discussion of the control measures which the Authority must institute at dangerous facilities, it is evident that in exercising these control functions it must carry out a large part of the normal functions of the manager and operator of the facilities. It is essential that the control be constructive as well as effective. In most cases, it would therefore be necessary for the Authority itself to operate dangerous facilities as a whole.

MINING AND CONCENTRATING OF URANIUM AND THORIUM

The unique role of uranium in the release of atomic energy has been stated. Control of the mining of uranium is clearly important. Any uranium ore which might be diverted at the mine must be subsequently processed in illegal ore concentrating plants, illegal chemical plants, and illegal piles or isotope separation plants before it is converted into material which can be used directly in atomic bombs. Each of these subsequent illegal operations provides an additional opportunity for detection. However, control at the mine is one of the most effective steps in helping to prevent the undetected manufacture of atomic bombs.

Prevention of diversion from known mines where uranium is the important constituent of the ore should not be a very complicated task. Most of the ore near the surface contains uranium at concentrations so low that diversion of significant amounts of uranium requires the handling of large and readily detectable amounts of ore. Mining of deeper ore bodies implies a limited number of exits, which can be readily found and checked. In cases where uranium is a by-product of a mining operation, the problem is more difficult.

Thorium is less important than uranium in the early stages of development of atomic energy. It will be somewhat more difficult to control thorium deposits than uranium mines. However, since the general methods of control are similar, thorium will be included with uranium in the following discussion.

Mine Boundaries

The principal problem which arises in the control of uranium and thorium mining is the delineation of the mining area which should be controlled by the Authority. Productive mines commonly occur in regions containing other structures which are geologically similar but are too lean in mineral values to warrant economical operation. These relatively lean deposits might, however, be worked surreptitiously as a source of uranium or thorium for unauthorized activities. Accordingly, when a region is known to contain deposits of uranium or thorium, it will be important for the Authority to make a geological and mineralogical survey which is sufficiently extensive to assure that

all significant deposits of uranium or thorium in that region have been located. The Authority must then decide which of the deposits are sufficiently rich to warrant placing under control and which are sufficiently lean so that only an occasional check, to establish that mining operations are not being conducted, is adequate to prevent diversion.

Authorized Mines

In locations containing relatively rich deposits of uranium or thorium, the Authority should be empowered, subject to principles set forth in the treaty, to decide which part of these deposits is to be developed for mining and which part should be held as an undeveloped operating reserve. The Authority should be able to specify the location of shafts and adits and the conditions of operation, including the rate of operation in some instances. Control of such developed locations would have as its primary objectives the assurance that the proper ore bodies are being mined at the specified rate and that all the ore mined is being delivered to the concentrating mill. In addition, the Authority must systematically guard undeveloped locations containing rich deposits and must occasionally check the regions containing leaner deposits, to insure that these regions are not being mined. When uranium or thorium can be obtained as by-products of other mining operations, appropriate measures must be taken to ensure the control of all uranium or thorium produced.

For its control measures, the Authority will require continuous participation in the operations at developed mines, and an inspection headquarters and assay and instrument laboratory in each producing region. Estimation of the amount of material which could be diverted without detection in the presence of a well organized control force obviously depends on the efficiency and the alertness of that force.

Mills and Refineries

Control of plant operations comprising concentration, purification, and conversion of uranium and thorium to salt or metal is somewhat different from control of mines, in that each of these operations may be conducted in a small, guarded area. As concentration operations are invariably closely associated with mining operations, they have been broadly covered already.

Each of these operations falls into a single broad pattern with respect to control. This pattern includes an accurate accounting of receipt of all uranium or thorium containing materials, a strict control and inventory of all in-process materials, accurate accountability of shipments of all uranium or thorium containing materials, and a rigid exit-inspection system. The general limitation of accountability resulting from the existence of tailings, waste liquors, weighing inaccuracies, and the like, may vary somewhat from plant to plant, but the possibility of diversion can, in each case, be kept down. Careful study of the problem by the Authority will lead to the establishment of satisfactory standards.

U-235 ISOTOPE SEPARATION PLANTS

The Authority should be empowered to decide in detail the characteristics of plants for the isotope separation of U-235, including their capacity and the degree of separation. This is necessary not only because of the danger of diversion but because such plants might be used to remove the denaturant from denatured fissionable materials. Thus, if denaturing is to provide any temporary security in the event of seizure of stockpiles of fissionable material, it is necessary that isotope separation plants be restricted as to capacity and as to the increase in concentration which they make possible.

Control of isotope separation plants would have the objectives of (1) establishing that such plants as are authorized cannot be effectively used in conjunction with stocks of denatured material available for potential seizure to produce significant amounts of material suitable for bombs, and (2) preventing diversion of significant amounts of fissionable material during the long-time operation of these plants.

For each type of isotope separation plant there is a limit within which even the strictest control cannot assure that diversion cannot take place undetected. The Authority should estimate this limit and construct only those plants whose aggregate capacity is low enough so that if the maximum undetected diversion did occur it would not constitute a military hazard.

The control measures generally applicable to dangerous activities which were listed above are all applicable to isotope separation plants and need not be repeated here. Since the activities of this control include many of the activities necessary for plant operation and since the control must be carried out in a very strict and effective manner, isotope separation plants for the production of fissionable material should be fully managed and operated by the Authority.

DANGEROUS PILES

From Chapter 2 it should be apparent that there are many possible scales and types of piles. Installations may be built to operate at any power level. It is likely that they would be held to be dangerous if operable at levels which would involve the presence or production of significant quantities of fissionable material. Below such levels, measures of control would still be necessary to prevent long-time violations or rebuilding of the installation, but such small plants would not require operation by the Authority. Larger plants, however, can represent a real military hazard.

In order to control a dangerous pile, the Authority must first make decisions regarding its general characteristics. A determination must be made of the type of pile, including the fuel consumed (natural or enriched material), the original investment of fissionable material, the operating schedule (which determines the amount of fissionable material present), and the design and location of the associated chemical plants. Since such dangerous facilities are potential sources of atomic bomb material, the scale, location, and type of the plant must be chosen in such a way as to minimize the utility and invulnerability of the plant in case of seizure. For example, plants with a large initial investment of fissionable material in suitable concentration for bombs would be more dangerous than those in which such a store was not present.

Only by making such decisions itself can the Authority be satisfied with the final design of the plant. More than that, the Authority must approve the overall design in detail, to insure that the specifications decided upon are in fact met. It must supervise construction to see that the design is actually followed. Finally, it must operate the pile to assure that no misuse is made of it.

Especially important is the insertion of materials in the pile and their removal from the pile. By careful and independent measurement of the total power as it varies with the time, together with full design data and information from experimental calibrating runs on the individual pile installation, it is possible to predict the maximum yield of fissionable material. When this is checked against the product delivered, any diversion should show up. But such a check demands continuous and intimate knowledge of the power level, shut-down times, and operating schedule, as well as the position and amount of all materials inserted and removed. All these requirements demand a resident control staff with such duties as these:

(1) To account for all fuel materials and fissionable products during fabrication, irradiation, storage, and chemical processing.

(2) To supervise all loading and unloading operations and to measure pile power levels and times of irradiation.

(3) To make periodic detailed surveys of all metering and recording equipment and all processing installations to guard against unauthorized changes.

(4) To determine the contamination of equipment, personnel, and the general area within and around the plant. Such knowledge enhances the possibility of detecting any diversion by making possible the detection of stray radioactivity from unauthorized handling of the active materials.

It is estimated that such measures would require a resident control staff of at least fifty technical employees for a sizable plant. Complete freedom within the plant and intimate knowledge of its operation and construction are necessary. Most of the duties of control are the same as the duties required for the successful operation of the plant. It is therefore essential that the operation of dangerous piles be in fact carried out by the Authority itself.

CHEMICAL PLANTS ASSOCIATED WITH PILES

As discussed in Chapter 2, the operation of a pile demands the operation of an associated chemical plant. Convenient handling of the radioactive materials would imply close physical proximity of the two related plants, but this may not be desirable from the standpoint of control. All chemical plants associated with piles are dangerous and should be operated by the Authority. If this were done, the piles themselves might be considered less dangerous in certain cases (see Chapter 5.)

Control of chemical separation plants would be effected by the general control measures outlined above. The following particular aspects of control in these plants are noted. The material charged to these plants will usually be intensely radioactive and so hetero-

geneous that reliable sampling and analysis will not be possible. To prevent diversion, it would therefore be necessary to insure that all fissionable material brought to a chemical separation plant was in fact dissolved and converted to a form in which reliable sampling and analysis could be conducted. Diversion would be more difficult at this stage because of the intense radioactivity of the material. After the fissionable materials were brought into solution, the standard methods of material accounting would be employed for detection of diversion.

Because of the intense radioactivity of the materials in process, it is often necessary to hold them to allow the radiactivity to decay. Nevertheless, operations in a chemical separation plant should be conducted with a minimum delay in the processing of materials in order to reduce the amount of fissionable material on hand.

RESEARCH ON ATOMIC WEAPONS

The production of atomic bombs should be prohibited under the terms of the treaty. However, the Authority would need to know the techniques and basis of bomb production in order to conduct proper denaturing and to understand fully the dangers of diversion and seizure of plants. Wholly new developments in weapons manufacture are by no means to be excluded, and the Authority must be better informed on all possibilities than any individual nation. Such research is clearly dangerous and should be carried on only by the Authority in central laboratories so staffed and so located as to afford a minimum of advantage to any single nation or group of nations in the event of seizure.

CHAPTER 5
CONTROL OF SAFE ACTIVITIES

INTRODUCTION

Four principal types of "safe" activity over which the Authority will need to exercise some degree of control are:

(1) Research in the atomic energy field, excluding atomic explosives.
(2) Production of small quantities of fissionable materials.
(3) Production of radioactive isotopes.
(4) Large-scale power generation in specially designed atomic energy reactors. (These are on the borderline between safe and dangerous activities and require special controls.)

It is felt that the management and operation of these activities may be entrusted to nations or individuals without danger of diversion of militarily significant amounts of fissionable material or without their constituting a serious hazard in the event of seizure, provided sufficient but limited control over them is exercised by the Authority. As will be noted in the following discussion, the frequency with which safe activities need to be inspected by the Authority and the degree of control which the Authority must exercise over their operation depends primarily on the amount of fissionable material on hand in safe installations and the rate at which fissionable material is fed to them and produced by them.

ATOMIC ENERGY RESEARCH

The activity in which the smallest amounts of fissionable material will probably be required and which may therefore be the least intensively controlled by the Authority is research which makes use of fissionable materials. Examples of this type of activity are experiments on neutron absorption cross-sections and other physical and chemical properties of fissionable isotopes and the construction and operation of small nuclear reactors for experimental purposes. The construction and operation of small isotope separation units might be permitted for the preparation of pure isotopes of various non-fissionable elements for nuclear research, provided that these units could not be used for separation of significant amounts of U-235.

Control measures deemed necessary for atomic energy research of the types illustrated above are as follows:

(1) Registration and licensing by the Authority of all laboratories wishing to engage in such research.
(2) Strict accounting by such laboratories to the Authority for all fissionable material produced or consumed in their operations.
(3) Submission of periodic reports by such laboratories to the Authority on their activities.
(4) Frequent visits by the Authority's staff to such laboratories in order to inquire at first hand concerning the research being conducted there. Representatives of the Authority must have complete freedom of access to these laboratories and to their records.

In authorizing laboratories to conduct research on atomic energy and in making fissionable materials available to them, the Authority should have the same considerations in mind regarding the dispersion of facilities and the limitation on the amount of fissionable material available in any one country as have been discussed in connection with dangerous activities.

PRODUCTION OF SMALL QUANTITIES OF FISSIONABLE MATERIALS

Laboratory production of small amounts of fissionable materials may be safely left to national or individual operation, provided the same control measures are instituted as have been recommended for atomic energy research. The Authority must limit the fissionable materials produced in this way in any one country so that their amount will be too small to constitute a military hazard.

PRODUCTION OF RADIOACTIVE ISOTOPES

One of the most valuable practical consequences of the development of atomic energy is the ability to make relatively large amounts of radioactive isotopes of nearly all the elements. These can be made in nuclear reactors containing only a small amount of denatured material and using up only a few grams of such material per day. The degree of control which the Authority will need to exercise over these reactors will depend upon the amount of fissionable material present in them and on the rate of consumption. For small installations, the same control measures recommended for atomic energy research laboratories will suffice. For larger installations, it will probably be necessary to have representatives of the Authority present continuously to witness operations.

LARGE SCALE POWER GENERATION

As already mentioned in Chapter 3, large power piles are on the borderline between safe and dangerous activities. However, for purposes of discussion, they have been put under safe activities in this report. Owing to the large amounts of fissionable material present in such piles, the Authority must exercise a much greater degree of control over them than over the safe activities just considered.

The design of the reactor must be very carefully checked by the Authority to insure that there will be no significant yield of fissionable material in the operation of the reactor and that diversion of fissionable material can be prevented. For example, the design must be such as to make irradiation of uranium in the pile impossible except in places authorized by the Authority. Similarly, the design of the pile must be such that the removal of fissionable material from it is physically impossible except at a limited number of easily observable points.

Representatives of the Authority must supervise all stages of the construction of the reactor to ensure that the unit as built corresponds in all details with the approved design.

Prior notice of the anticipated operating schedule must be given to the Authority for its approval, so that it can maintain a proper balance between production and consumption of fissionable materials.

The Authority must maintain a group of inspectors continuously at the power plant to assure itself that fissionable materials are not removed from the pile during operation. By proper design of the pile, it should be possible to minimize the size of this staff and its interference with normal operations. The principal reason for not requiring the full management and operation of these installations by the Authority is the fact that only an inspection force would be necessary and this force would not need to fulfill many of the normal operating functions of the management.

In addition to these special control requirements, the control measures listed under atomic energy research should be in effect for large atomic power plants.

Implicit in this discussion of atomic power plants is the necessity for all associated chemical plants to be fully managed and operated by the Authority. The Authority would supply the fissionable material for the power plants in accordance with their established power levels and design characteristics. The partly consumed materials would be returned to the Authority for reworking in its chemical plants. If these chemical plants were operated by nations or individuals in conjunction with power plants, the opportunities for diversion would be intolerably great.

The necessary restrictions on the design and operation of atomic power plants may make them less attractive economically as a field for national or private development. Unfortunately, this is inherent in the dual character of atomic energy technology; installations large enough to be of importance in the generation of power necessarily contain and consume militarily significant amounts of fissionable materials. The only way these installations can be safely left in national

or private hands is by placing serious restrictions on their design and operation. Indeed, it might prove necessary, depending on the design of the pile, to have operation in the hands of the Authority.

CHAPTER 6

DETECTION OF UNAUTHORIZED ACTIVITIES

REQUIREMENTS OF ADEQUATE DETECTION MEASURES

Detection measures will have to be sufficiently extensive and dependable to promote a feeling of security among all nations and confidence that the Authority is capable and is worthy of the great responsibility placed upon it. Any system of inspection or detection, no matter how complete, will be only as good as the individuals operating the system. The selection of individuals to man the system for the detection of unauthorized activities should be given careful consideration to assure that men of integrity, imagination, and technical competence direct the work. It will be easier to attract this type of personnel if the program involves promoting the safe utilization of atomic energy as well as inspection to detect unauthorized activities.

By thorough study and research into all phases of the atomic energy program, novel and dependable means of detecting certain types of operations can be devised. The personnel directing the detection program should participate actively in the research and be fully informed of all developments in the atomic energy field. The better informed the directing personnel are, the more likely it will be that they and the organization they direct will be able to detect unauthorized activities. The challenge of the responsibility for being the best informed men in the field should keep the organization alert and active and should increase the confidence of the nations of the world that the danger from undetected activities is a minimum.

If too great emphasis were placed on the purely negative inspection function of the organization, men with imagination, initiative, and a thorough understanding of the principles and techniques of the atomic energy program would not be so easily attracted to the key positions. There would be a tendency for detection to become a matter of policing and espionage measures, and this would be certain to result in friction. In order that the detection program may be a success, it is necessary that friction be kept at a minimum and that there be no grounds for charging that the Authority is carrying out measures which constitute virtual industrial espionage and which disregard the cherished rights of the various nationals involved.

INFORMATION TO BE OBTAINED FROM DETECTION MEASURES

Introduction

The primary objective of detection measures is to provide the specialized information concerning the scientific and industrial activity of a country necessary to assure the Authority that no unauthorized activities connected with the production of atomic weapons are being carried out. The specific detection measures of most value in providing this information will depend upon the particular type of information required and on the means available for securing it.

Generally speaking, three formal means of acquiring information are open to the Authority. These are:

(1) The accumulation of information during the Authority's normal control of authorized activities.

(2) Formal reports on specified topics submitted by individual nations to the Authority.

(3) Direct inspection by representatives of the Authority whose primary function is to secure specific information for the Authority.

The extent to which the Authority would have to avail itself of these formal means for securing information would depend on the degree of cooperation between the Authority and the normal scientific and industrial life of a country. The greater the collaboration of the leading scientists and engineers of a country with the members of the Authority's staff, the less the need for formal reports and direct inspection. Under circumstances where extensive use was made of the facilities and services of the Authority, information gathered informally by the Authority's representatives in the course of their normal contacts would provide much of the necessary assurance that unauthorized activities were not being undertaken. On the other hand, under circumstances where extensive use was not made of the facilities and services of the Authority, detailed reports on a number of types of scientific and industrial activity and considerable direct inspection would be required to provide the Authority with the information needed to establish that unauthorized activities were not being undertaken. The five principal types of information which must be secured by the Authority by one means or another are briefly described in the following paragraphs.

Geological Occurrence of Uranium and Thorium

The Authority must know all the locations in the world where significant deposits of uranium and thorium occur and should also be familiar with those areas in which geological formations indicate the probable occurrence of these elements.

Location of Large Mines and Underground Structures

The Authority should be familiar with the location of all large mines to assure itself that such mines are not capable of producing significant amounts of uranium or thorium either directly or as a by-product from normal operations. It should be familiar with the location of all large underground structures to make sure that they are not being used to conceal large industrial plants which might be used for isotope separation or as nuclear reactors.

Large Producers and Consumers of Power

The Authority should have sufficient familiarity with the principal producers and consumers of power and the amounts of power distributed to individual consumers so as to be able to locate those plants making use of enough power to warrant investigation as possible isotope separation plants.

Large Industrial Establishments

One of the premises on which the success of measures for the detection of unauthorized activities is based is that installations capable of converting uranium or thorium, in a relatively short time, into enough atomic bombs to be of military value must be large industrial undertakings. For example, the gaseous diffusion plant at Oak Ridge has a floor area of over 5,500,000 square feet and cost about $500,000,000. It is true that smaller plants are militarily significant and that new installations might well be built at lesser cost. Nevertheless, if the Authority were familiar with the location of all large industrial establishments and knew their primary function, it could be fairly sure that no dangerous unauthorized plants for the production of fissionable materials were in existence.

Activities of Leading Scientists and Engineers

A valuable source of information for the Authority would be the nature of the activities of leading scientists and engineers throughout the world. To date there has been no single phase of the atomic energy program that has not required the combined efforts of large numbers of scientists and engineers. Therefore, the Authority should be interested in the activities of unusually large groups of scientists and engineers assigned to any project. The activities of leading scientists and engineers would furnish valuable information as to the trend of interest in a country. Lack of information concerning the activity of leading scientists and engineers would be a danger signal and might call for investigation by the Authority.

SUGGESTED DETECTION MEASURES

In contrast to the limited number of specific measures discussed earlier in this report for the control of authorized, declared operations and operations carried on exclusively by the Authority, a greater variety of less definite measures would be required for the detection of unauthorized operations. This is due in part to the large number of ingenious ways in which concealment might be attempted, in part to uncertainty as to where illegal installations might be located, and in part to the need for adopting those inspection measures which interfere least with normal activities. This leads to so many possible combinations of inspection measures that only a few examples can be given in this report.

Informal Assembly of Information by the Authority

It has been pointed out that, if the Authority has extensive facilities in the countries of the world and is working intimately with the leading scientists and industrialists of these countries, it would acquire in performing its normal functions most of the information it would need to assure that unauthorized activities were not being undertaken. A number of examples of this will be given.

One of the most important constructive functions of the Authority would be the location and development of deposits of uranium and thorium. For this positive function the Authority should engage in extensive prospecting, which would necessarily acquaint it not only with those locations where uranium and thorium do occur but with those geological formations in which these materials might occur. In carrying out this function, the Authority would have intimate contact with the mining profession throughout the world. This would also

serve to acquaint it with the location of large mines and would help to indicate which of these mines contain significant deposits of radioactive minerals.

By conducting advanced research in nuclear physics, isotope separation, and other subjects related to atomic energy utilization, the staff of the Authority would be in touch with scientists of individual countries who are most familiar with these subjects. This would make it easier for the Authority to keep track of the general fields of endeavor of those scientists who would be most valuable to individual nations if they undertook unauthorized activities in these fields.

Through the production of large amounts of power from atomic energy the Authority would have close contacts with the producers and consumers of power in the principal countries of the world.

In licensing various safe types of activity in the atomic energy field and in providing fissionable materials to establishments working in this field, the Authority would acquire valuable information as to which companies and which engineers or industrialists would most likely be of value in carrying on unauthorized activities.

The Authority, with its own plants and those of its licensees, would be familiar with the location and probable function of all large industrial establishments. A group of intelligent men, with the responsibility of locating large plants and of knowing in a general way what their function is, can secure this information with a surprisingly small number of contacts made during the carrying on of the more constructive affairs of the Authority.

By careful analysis and cross-checking of information in each place during the normal course of the Authority's work, it should be possible to tell which regions of the world or which mines or industrial establishments might possibly be engaged in unauthorized activities and should therefore be subjected to direct inspection.

Formal Reports

To supplement the informal information noted in the preceding section and to minimize the amount of direct inspection employed, the Authority should receive commitments from all participating nations to submit reports on certain technical topics of value in detecting unauthorized activities. These reports, taken at their word, would be of value in describing most of the activities of a country associated with the utilization of atomic energy. The reports should also be examined with a view to detecting deliberate omission or falsification of information since, if such deliberate errors are detected, a very valuable indication of unauthorized activity will have been found. Errors and omissions may be found by intercomparison of reports on different subjects from a single country, intercomparison of reports from different countries, comparison of reports with informal information secured during the normal activities of the Authority, and by spot checks through direct inspection.

The Authority should request reports on the following subjects:

(1) *Mining.*—The Authority should receive reports on all major mining operations.

(2) *Large Plants.*—An initial report and subsequent annual reports on the location and nature of all large plants.

(3) *Engineering Construction.*—Reports on the beginning of all new engineering construction of significant magnitude.

(4) *Power Plants.*—Annual reports on the location of all large power-generating stations.

(5) *Consumers of Power.*—Annual reports on the location of all large users of heat or electric power, giving the nature and amount consumed.

(6) *Specific Equipment or Commodities.*—Periodic reports on the production, shipment, location, and use of the following specific equipment and commodities, which are of particular value in the construction and operation of certain types of isotope separation plants and piles.

- (a) Analytical mass spectrometers.
- (b) Diffusion barriers in quantity.
- (c) Gas centrifuges.
- (d) Electromagnetic isotope-separation units.
- (e) Very pure graphite in large amounts.
- (f) Heavy water.
- (g) Beryllium or beryllium compounds.

Direct Inspection in General

Methods of detecting making use of informal measures or formal reports are valuable preliminaries to the detection of unauthorized activities but, since they could seldom result in definite proof of the existence of such activities, they obviously must be supplemented by direct inspection of suspected places, mines, and plants.

Direct inspection should not be used indiscriminately, because of the risk of antagonizing a nation or its citizens. The need for a particular investigation of this type should be demonstrable, and the methods of inspection to be employed should be chosen with a view to minimizing resentment. In the following discussion it should be remembered that, although the Authority would have the right to inspect certain places or facilities, it should be so organized that these rights could not be exercised capriciously.

The direct inspection which the Authority may use to establish the existence of unauthorized activities in the atomic energy field will be discussed under the following headings:

(1) Aerial surveys.
(2) Ground surveys.
(3) Inspection of mines and underground structures.
(4) Inspection of industrial facilities.
(5) Special features.
(6) Access.

The principal objectives of direct inspection will be noted and its utility evaluated.

Aerial Surveys

Aerial surveys would be a rapid means for receiving general information concerning the location of mines, construction projects, and other industrial activity in large, sparsely settled areas. Their principal disadvantage would be the accumulation of information irrelevant to the Authority. Aerial surveys would be most useful in relatively sparsely settled areas, in which mines or industrial plants are easy to detect by contrast with their undeveloped surroundings. Since ground surveys in sparsely settled areas are tedious and difficult, it is seen that aerial and ground surveys complement one another.

Ground Surveys

The principal objectives of ground surveys would be to locate mines and large industrial buildings, to conduct geologic surveys, to make physical measurements useful in locating unauthorized activity (such as seismic measurements to detect blasting), and to sample materials for radioactive elements. Ground surveys would be of specially great value if the Authority were allowed free access to all areas of a country without advance notice. If advance notice were required, it might be possible to stop or conceal unauthorized activities.

Generally speaking, investigation by ground parties would pick up less irrelevant information than investigation by aerial surveys. A ground party would be almost essential in a crowded, built-up area in which an aerial survey cannot identify individual installations. The procedure frequently might be to send in a ground party to examine small regions deemed worthy of detailed investigation as the result of a broad aerial survey.

Inspection of Mines and Underground Structures

Inspection would be required to determine whether mines were capable of producing dangerous amounts of uranium or thorium and whether underground structures concealed unauthorized facilities, such as piles or isotope separation plants. The most satisfactory way in which to deal with the location and inspection of mines and underground structures would be to have an inspection force of personnel familiar with the mining of uranium and thorium. These men would talk with prospectors and mining engineers and gather information on new mining developments. They would spot-check suspected structures and would inspect operating mines thought possibly to be producing uranium or thorium as a by-product.

Very large plants to extract elements from sea water are worthy of inspection to establish that uranium and thorium are not being concentrated in them. However, it is not likely that plants would be built for this purpose, since there are only a few parts per billion of these elements present.

Inspection of Industrial Facilities

The consumption of large amounts of steam or of electric power is one of the distinctive features of plants for concentrating U-235. Accordingly, the Authority should have the right to inspect power plants and distribution systems for electricity, steam, oil, and gas in order to locate large consumers of power. This is of sufficient value for the

Authority to have access to such installations, preferably without prior notice.

It will frequently be desirable for inspectors to enter industrial establishments to determine whether unauthorized activities are being conducted or to check information reported by the company or government operating the plant. There are obvious difficulties inherent in such inspection, but it cannot be dispensed with. Without access of this type, proof of unauthorized activities cannot be secured.

One fortunate circumstance regarding the inspection of buildings is the distinctive character of unauthorized activities in the field of atomic energy. Uranium and thorium in process can be readily detected by their radioactivity and chemical properties. Isotope separation plants make use of unique types of equipment in large amounts. Piles are unlike any other type of industrial structure, with their massive shielding, intense internal radioactivity, and enormous rate of heat dissipation. Inspection of buildings can therefore be reliably conducted by men expert only in atomic energy operations who could determine whether unauthorized activities relating to atomic energy were being conducted, without learning much about the character of legitimate operations.

Special Features

Methods available for detecting isotope separation plants include checking the manufacture and shipment of special equipment used primarily in these plants. Certain equipment is necessary to isotope separation plants and of such limited usefulness to other industries that application of inspection measures to manufacturers and users of such equipment may be worthwhile. These measures might well include maintenance of a register of all such equipment, periodic accounting for it, and inspection of shipments from manufacturers thought likely to be making such equipment. This sort of inspection might be applied to the following types of equipment:

(1) Analytical mass spectrometers (all processes).

(2) Diffusion barrier (gaseous diffusion process).

(3) Gas centrifuges with high peripheral speeds (gas centrifuge process).

(4) Electromagnetic separation units (electromagnetic process).

A characteristic of piles is the use of moderator materials to slow down the neutrons. Such materials are very pure graphite, heavy water, and beryllium. Appropriate inspection measures should be instituted in regard to the production, storage, and shipment of these materials.

A characteristic of large piles is the extensive cooling facilities required. This is of great importance for detection. The only practical methods of removing such large quantities of heat are discharge to natural bodies of water or to the atmosphere. Air cooling, being relatively inefficient, implies extremely large installations and probably becomes impracticable for any but a small scale plant. Water is practically essential in the cooling of such piles. This implies that these piles must be constructed near a sizeable natural water supply, i.e., a lake or river. Accordingly, engineering construction in such areas should be investigated.

Access

It is obvious that all these inspection measures require various degrees of access to a country. Without access, direct inspection cannot be performed successfully. Inspectors must be permitted to travel without restraint and to carry out investigations without undue interference. Care must be taken to inspect only so far as necessary to confirm or disprove suspicions. In some cases inspection of receiving and shipping rooms and platforms might be sufficient. In other cases a thorough inspection, including taking samples from processes, might be necessary. In all cases the right of nationals and industries should be observed to the greatest possible extent consistent with fulfillment of the functions of the Authority.

CHAPTER 7

DEGREE OF SECURITY AFFORDED

The degree of security against the use of atomic weapons afforded by the control system described in this report is dependent upon the extent to which the following very important conditions are fulfilled.

(1) The Atomic Development Authority should be staffed with imaginative, technically competent men of the highest integrity. Men of this caliber should be afforded adequate incentives to join the organization, such as opportunity to practice their chosen professions and professional recognition of their work with the Authority. It will be of the utmost importance that the staff of the Authority be as clever, resourceful, and technically competent as any national group.

(2) The Authority's purpose of promoting the safe utilization of atomic energy should be an essentially positive one, to which the function of preventing unauthorized activities would be subordinate. If negative activities were dominant, it would be impossible to attract technically able men to the Authority and to secure that degree of national cooperation required for successful functioning of the atomic energy plan.

(3) The Authority should participate actively in research, development, and production to the end that it will be better informed than any national group concerning the activities it must control and detect.

(4) The Authority should be empowered, and should have sufficient flexibility, to change its procedures, privileges, and scale of activities as the use of atomic energy increases and the technology associated with it changes.

(5) In the pursuit of its detection activities, the Authority must have access under reasonable conditions to all areas in all nations as described in Chapter 6.

(6) The Authority should be set up promptly and agreement concerning its permissible control methods should be reached as soon as possible.

All of these conditions imply a very considerable degree of international cooperation and a real willingness to make the Atomic Development Authority work. Even if these conditions are fulfilled, the technological control measures described in this report provide security only in the following respects:

(1) Providing deterrents, in so far as technical measures can do so, to the use of atomic energy for destructive purposes.

(2) Prevention of surprise use of atomic weapons in quantity by providing unambiguous evidence of the intent of a nation to produce them.

(3) Delay in the production of a militarily useful number of atomic weapons after evidence of intent to produce them has been given.

The degree of security in these respects afforded by the control system described in this report will be evaluated on the assumption that the six favorable conditions just enumerated will be fulfilled.

The measures purposed in Chapters 4 and 5 for the control of authorized activities would provide a degree of security against surprise atomic warfare. They would assuredly prevent large scale diversion of fissionable materials to atomic weapons for a number of years, provided that the scale of authorized operations was low enough so that a small percentage diversion did not represent a serious military hazard. However, the longer authorized activities are conducted, the less security would be afforded by the control system because of the possibility that small amounts of material accumulated over a long period of time might build up to a real military advantage. If only authorized facilities were in existence, it is estimated that from three months to one year would have to elapse after seizure of such facilities before a nation intent on making atomic weapons could produce a militarily significant number.

Successful detection of unauthorized activities is subject to much greater uncertainty than control of authorized ones. Nevertheless, except for the small but finite chance of failure inherent in any form of inspection, it is thought that the interlocking and overlapping nature of the technical inspection measures outlined in Chapter 6 would provide reasonable security against surprise atomic warfare, provided the six conditions given above are fulfilled. This will be true as long as production of militarily significant amounts of fissionable material remains an industrial enterprise of great magnitude. If methods for producing fissionable material are radically simplified, the chances of evading the inspection measures suggested in this report would be greatly increased. The Authority therefore must keep in the forefront of technical developments in the field of atomic energy and must have the power and the competence to adapt its controls to changing conditions.

Atomic Energy and U. S. Patent Policy

Part 2: Patent Provisions of the Atomic Energy Act . . . Casper W. Ooms

In the Congressional debates preceding enactment of the Atomic Energy Act of 1946 the patent provisions were the subject of more controversy and argument than any other portion of the legislation. A great deal of the discussion disclosed a lack of study of the legislation and a complete failure to appreciate the fundamental effect of the basic provisions of the statute. To understand the patent provisions of the Act it is necessary to review some of the powers entrusted to the Atomic Energy Commission.

The Atomic Energy Act declares it unlawful for any person to manufacture, produce, or refine fissionable material, or to own any facilities for that purpose. [Sec. 4 (a) and (b)]. The Act makes the Commission owner of all facilities for that purpose. [Sec. 4 (c) (1)].

The Act further makes all fissionable material, whenever produced, and all rights therein, the property of the Commission. [Sec. 5 (a) (2); Sec. 9 (a) (1)].

Finally, the Act declares it unlawful for any person to manufacture, deal in, or acquire any device utilizing fissionable material or atomic energy as a military weapon, except upon authorization of the Commission, and the Commission is exclusively authorized to operate in the field of atomic military weapons under such directions as the President may from time to time give the Commission and the armed forces. [Sec. 6].

The implications of the grant of these extensive powers to the Commission and their prohibition to the community at large readily manifest a departure from the general principles of property ownership and freedom of conduct found almost without parallel in our history. Congress was convinced of the need of this exceptional treatment in an extended debate in which it considered the extraordinary problem with which it had to deal, the need for responsible administration of the entire field of atomic energy, the necessity for the greatest possible secrecy of operations in the field until international control had been effected, and the indispensability of assurance that a weapon of the potentialities of atomic energy would remain under government control.

Congress thus removed from private ownership and control the entire field of production of fissionable materials and the entire field of their utilization in military weapons. In addition, by provisions discussed below, the Commission was given a licensing power over the utilization of fissionable materials. [Sec. 7]. The patent provisions of the Act are designed to meet the problems which these innovations in the control of atomic energy raised.

The Atomic Energy Act revokes any patent which may have been granted and forbids further issuance of patents for inventions "useful solely in the production of fissionable material or in the utilization of fissionable material or atomic energy for a military weapon," [Sec. 11-(a) (1)] and revokes any rights and prohibits future acquisition of rights under patents to the extent that the inventions covered by such patents are used " in the production of fissionable material or in the utilization of fissionable material or atomic energy for a military weapon." [Sec. 11 (a) (2)].

These provisions are directed to patents in the two fields entrusted exclusively to the Commssion, the fields of (1) production of fissionable materials, and (2) their utilization in military weapons. Inasmuch as those fields of activity are entirely proscribed to the community at large, there remained little room for normal operation of the principles of the patent system. The patent, we have seen, makes no attempt to license the use of the invention covered by it; on the contrary, the only effect of the patent is to confer on the patentee the power to exclude others from the practice of the patented invention. Thus, the granting of patents upon processes, machines, or even the materials previously required for the production of fissionable materials, a field from which the patentee himself is even excluded by the Act, would be a nullity. Presumably the only actor upon whom the exclusionary power of the patent could be exercised would be the commission, to whom is exclusively entrusted the field in which the invention of the patent is operative. Obviously the grant of such patents would constitute a futile, if not embarrassing, procedure.

In the field of military weapons utilizing fissionable materials the same considerations apply, and in addition, the very important additional consideration that the efficacy of military weapons is frequently dependent upon the maintenance of secrecy with respect to their manufacture and characteristics. The need for secrecy dictates the utter unsuitability of the patent in the field of military weapons. It may seriously be questioned whether the patent lends itself in any way to the business of manufacturing devices that have no other use than as military weapons, as the patent is designed to effect disclosure, a purpose in complete contradiction to the secrecy demanded with respect to weapons of war. Congress has in fact made special provision for the prolongation of prosecution of patents upon inventions "important to the armament or defense of the United States"[1] and has empowered the Commission of Patents to order secrecy with respect to and to withhold the grant of patents upon inventions where the disclosure thereof might be "detrimental to the public safety or defense."[2]

To the extent that the Atomic Energy Act revokes patent rights already conferred, the statute provides for the payment of "just compensation". [Sec. 11 (a) (1) and (2)]. To the extent that it forbids future patents it provides that an application may be made to the Commission for an award, which the Commission is empowered to grant. [Sec. 11 (e) (2) (C) and (3) (C)].

To insure the enforcement of the provisions with respect to inventions in the production of fissionable materials and their utilization in military weapons, the Act requires the inventor to report the invention to the Commission within sixty days after completing the invention, the date of enactment of the Atomic Energy Act, or first learning that the invention is useful in either of the proscribed fields. [Sec. 11 (a) (3)].

The Act further revokes any rights conferred by any issued patent and prohibits the acquisition of rights in patents hereafter granted to exclude the use of the inventions covered by such patents "in the conduct of research or development activities in the fields specified in Section 3" [Sec. 11 (b)]. Section 3 specifies the research and development fields in which the Commission is directed to encourage investigative work in the broadest possible terms, including nuclear processes; atomic energy; utilization of fissionable and radioactive materials for medical, biological, health, or military purposes; industrial uses; and the protection of health during research and production.

The extent of this provision of the statute is not clear. Conceivably it could be urged that all equipment used in the specified research is free of patent control. If so, the researcher could proceed to manufacture all of the apparatus and equipment needed for his work, although that would hardly appear feasible, without any regard to the patents upon such equipment. If that is the interpretation to be accorded this provision it is the most sweeping of the patent provisions in the Act, as it would free from patent

control every type of device and machine known, from such simple things as electric motors to the most specialized type of electronic detectors. Another available interpretation is that only the specific use of the equipment in the problem of research or development upon it is free of patent control, and that the manufacture and sale of the equipment still falls within the power of the patentee to exclude.

What the Act has apparently attempted is the express enactment of a vaguely recognized principle of patent law, that "an experiment with a patented article for the sole purpose of gratifying a philosophical taste, or curiosity, or for mere amusement, is not an infringement of the right of the patentee"[3] discussed in the first part of this paper. What the statute has attempted is a positive protection of the researcher in the field of fissionable materials against interference with or prohibition of his work by the assertion of patent rights.

Another patent provision in the Act is that which empowers, and makes it the duty of, the Commission "to declare any patent to be affected with the public interest if (A) the invention or discovery covered by the patent utilizes or is essential in the utilization of fissionable material or atomic energy; and (B) the licensing of such invention or discovery under this subsection is necessary to effectuate the policies and purposes of this Act." [Sec. 11 (c) (1)]. The Act then proceeds to license the Commission to use such inventions in performing its functions, and to license the use of such inventions to any person licensed by the Commission under Section 7 of the Act to the extent that such invention is used in carrying on the activities authorized by his license, subject in both cases to the payment of reasonable royalties to the patent owner. [Sec. 11 (c) (2)].

In order to render these licensing provisions effective the Act proceeds with an express prohibition against the issuance of any injunction under the patent so licensed. [Sec. 11 (c) (3)].

These provisions were bitterly contested in the debates in the House of Representatives. They were recognized as a form of compulsory licensing of patented inventions, an issue which is constantly under debate. The limitations by which the licensing was surrounded, although extremely broad, were almost entirely overlooked. These may now be examined.

In the first place it is necessary that the patented invention to which these provisions of law apply be one that utilizes or is essential in the utilization of fissionable materials or atomic energy; next it is necessary that licensing is necessary to effectuate the policies and purposes of the Atomic Energy Act. The "policies and purposes" of the Act recited in Sections 1 (a) and (b), generally express the intention that "the development and utilization of atomic energy shall, so far as practicable, be directed toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace", and the purpose to provide for major programs relating to atomic energy, to assist and foster private research and development and to encourage maximum scientific progress, dissemination of technical information, to insure the broadest exploitation of the fields, etc. Only when these two limitations are observed may the Commission impress a patent with the declaration that it is affected with the public interest.

The very nature of the entire subject of atomic energy is such that it is difficult to conceive of any phase of its utilization that does not compel a recognition of the public interest which dictated this legislation. What Congress has attempted by this compulsory licensing device is to insure that no license to utilize fissionable materials granted under Section 7 of the Act, which contains elaborately detailed provisions to insure the granting of such licenses on a non-exclusive and non-discriminatory basis, shall be nullified by the owner of a patent who may exercise his patent rights on an exclusive and discriminatory basis.

Such provisions in the law do not present the novelty which was asserted for them during the debates on the legislation. In spite of a public impression to the contrary, the patent law has long contained specific provisions of the same general effect, enabling the United States to employ or have any manufacturer employ for it any patented invention without license from the patent owner[4]. That Act provided that the patent owner could sue in the Court of Claims for reasonable compensation for the use of the patented invention, and denied even that relief to employees of the United States. In 1942 the law was further modified to provide further that the United States could order suspension of the terms of licenses under patents where the head of a Government department believed the royalties prescribed in the license to be unreasonable, and to fix fair and just royalties in the place of those agreed upon by the patent owner and the licensee.[5]

The principle that the public interest may warrant modification of the complete power of the patent owner to select his licensees and fix the terms of his licenses had more recent recognition in the first report of the National Patent Planning Commission:

If it be conceded that operations under licenses from the Atomic Energy Commission are impressed with considerations of the national defense or public health or public safety, and the specified patent involved is necessary to the licensed operation, the compulsory licensing provided for by the Atomic Energy Act would appear to fall within the principle announced by the National Patent Planning Commission[6].

The Act provides for the payment of reasonable royalties for the use of patents licensed under this provision, in the first instance by a Patent Compensation Board conducted by the Commission, and for review of this determination by the Court of Appeals for the District of Columbia. Similar provisions are made to determine and review the just compensation to be paid under the Act for patent rights revoked by the statute, and for the rendering of an award to those who disclose to the Commission inventions in the production of fissionable materials or their utilization in military weapons, although the details of the remedy vary. [Sec. 11 (e) and 13 (a)].

One final provision of the Act [Sec. 11 (d)] requires consideration. Under this paragraph, the Commission is authorized to purchase or condemn with just compensation any invention useful in the production of fissionable material or in its utilization for military weapons, or which utilizes or is essential to the utilization of fissionable material or atomic energy, or any patent or patent application covering such an invention. Provision is made for the determination of the compensation by the Patent Compensation Board, and review of the determination by the Court of Claims or the United States District Court.

In brief review, the Act provides an elaborate but flexible procedure designed to prevent the acquisition of patents in the fields in which the Atomic Energy Commission is given an absolute governmental monopoly, the fields of production and military utilization of fissionable material, and to prevent the assertion of patent rights against research activities in the field of atomic energy or against Commission-licensed operations in the utilization of fissionable materials. The Act also empowers the Commission to purchase patent rights in those fields, and requires the payment of compensation for all rights purchased by the Commission or revoked by the statute.

FOOTNOTES

1. R. S. 4894 (Title 35, U.S. Code, Sec. 37)
2. Act of Oct. 6, 1917 (Title 35, U.S. Code, Sec. 42)
3. Walker on Patents (Deller's Ed.), Sec. 450
4. Act of June 25, 1910 (Title 35, U.S. Code, Sec. 68)
5. Act of Oct. 31, 1942 (Title 35, U.S. Code, Sec. 89)
6. Report of the National Patent Planning Commission (1943) III B. (1)

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EDITORIAL—continued from page 1

might be useful in war technology. Every scientific result is potentially important in future total war. There is no such thing as "science for peace" and "science for war," but every forward step in science increases the potentialities of mankind in both war and peace.

The fundamental dilemma which the Atomic Energy Commission must face is whether to continue the opportunistic policy of releasing—more or less reluctantly—the scientific information which at the moment appears to be more or less "innocuous," and to keep secret the scientific facts which our past experience has indicated to be particularly relevant to war—technological problems. Should we not make the bold decision of actually following the principle laid down in the Truman-Attlee-King declaration—that of keeping secret only the technical know-how, the kind of things which were to be found, in peacetime, in patent applications rather than in scientific journals? Would not such a decision, taken on a unilateral basis and without expectation of reciprocity, gain more by assuring our continued scentific leadership, than harm us by saving others the trouble of finding out certain facts of nature by their own experiments? Only then could we hope to obtain, on this basis, the co-operation of scientists in many other countries, a co-operation which under the conditions of a free flow of scientific information will be as available to us as our own scientific production. E. R.

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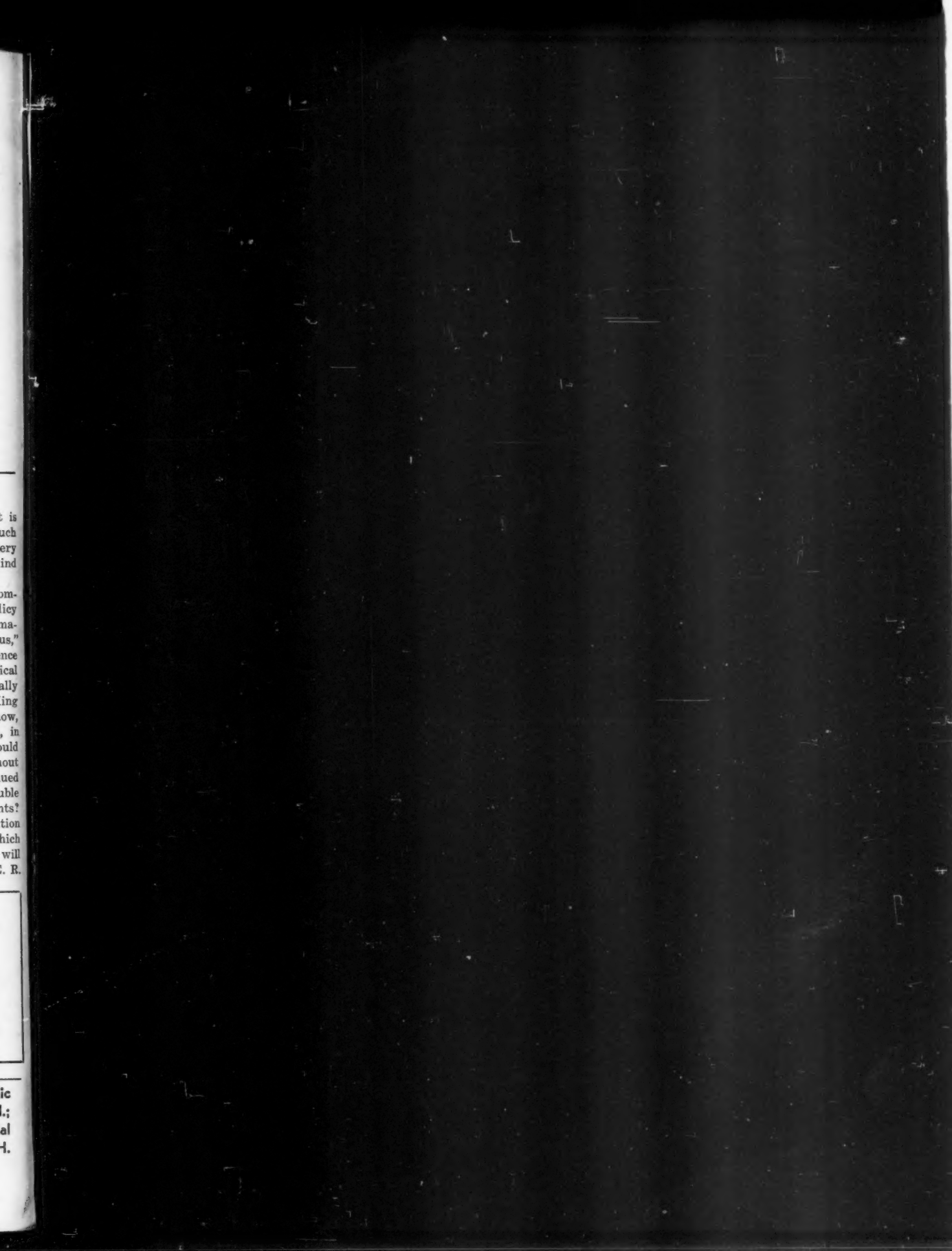
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